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ARMY ORDNANCE

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THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Cross-Country Cargo Carriers—Artillery Design

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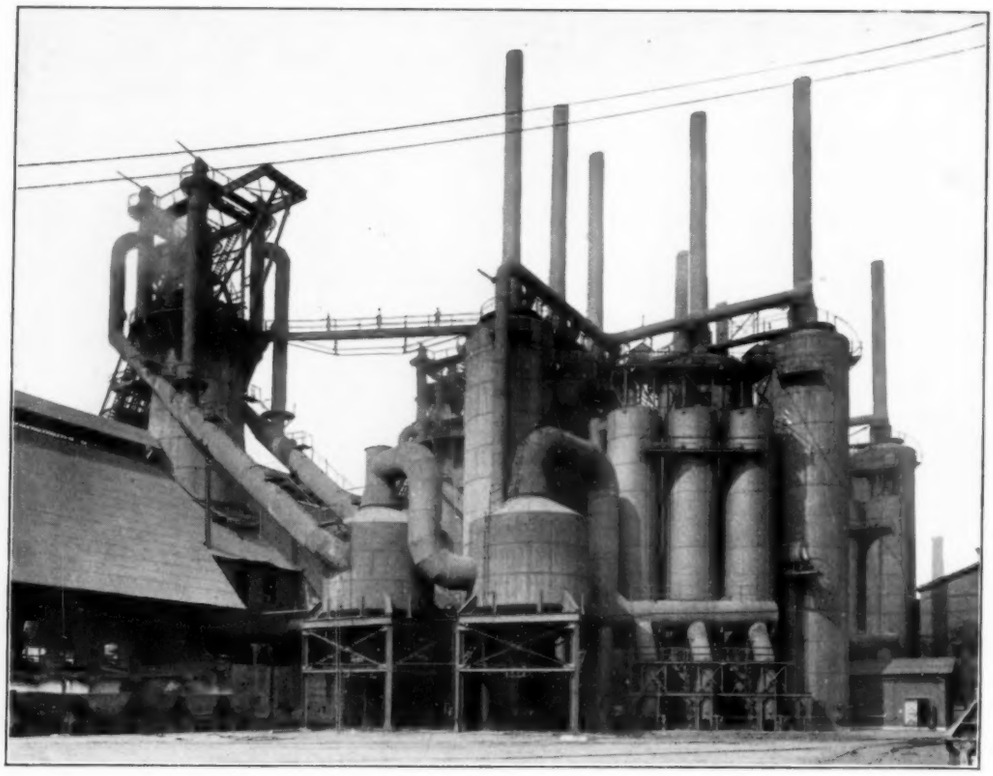

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ARMY ORDNANCE

THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Pledged to Public Service in Effecting Industrial Preparedness for War as Our Strongest Guarantee of Peace

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WILLIAM W. COLEMAN, *Vice-President*

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Fifth Annual Meeting

of

The Army Ordnance Association

The American Iron and Steel Institute

Participating

October 26, 1923

The Fifth Annual Meeting of the Army Ordnance Association will be held at the Aberdeen Proving Ground, Friday, October 26, 1923. Authority has been given by the Acting Secretary of War for the use of the Proving Ground on this occasion. The Acting Secretary, Colonel Dwight F. Davis, in transmitting the authorization has expressed his appreciation of the work of the Association, and we take the liberty of publishing his letter herewith.

The exact details of the meeting, including train and meal arrangements, and the complete program of exhibits, will be published in the September-October issue of ARMY ORDNANCE which will be in the hands of members in ample time for them to make their individual plans.

However, there are several "advance" thoughts we want to discuss here. First, we take great pleasure in announcing that The American Iron and Steel Institute will participate with us at this meeting. The Institute, through its Secretary, Mr. Edmund A. S. Clarke, has entered in a most wholehearted fashion in joining with us in the meeting. At its own semi-annual gathering in New York City last May the members of the Institute expressed themselves as pleased with the prospect of a visit to Aberdeen. Special train arrangements will be made for these and other guests from New York, Philadelphia, Baltimore and Washington, details of which will be announced later. We have attempted to express editorially our pleasure in anticipating a meeting of the Army Ordnance Association in which the American Iron and Steel Institute will participate.

WAR DEPARTMENT
WASHINGTON

June 14, 1923.

Mr. Benedict Crowell,
President, Army Ordnance Association,
Washington, D. C.

My dear Mr. Crowell:

In reply to your letter of the 14th instant, the War Department is indeed glad to grant authority for the Army Ordnance Association to hold its next annual meeting at the Aberdeen Proving Ground next October and to have with it the American Iron and Steel Institute in order that the two societies may hold a joint meeting at the Proving Ground.

I appreciate the work the Army Ordnance Association is doing in the furtherance of industrial preparedness and am glad to be able to give practical expression to this appreciation by granting authority for the meeting as requested.

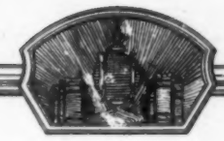
I am going to attend this meeting. I feel that it is an interesting and helpful contribution to the cause of industrial preparedness.

Sincerely yours,

DWIGHT F. DAVIS,
Acting Secretary of War.

Every member of the Army Ordnance Association is invited to attend the meeting. Individual notices and invitations will be sent to all members about October 1st. The meeting this year will merit the attention and interest of everyone who can possibly be there. A day complete with exhibits and features will be had and every member is asked to set aside this date *now* and let nothing interfere with his being present. Finally, every member is urged to be present himself and promote the ideals of the Association by bringing a new member with him. The mission of the Army Ordnance Association—to effect industrial preparedness for war in a spirit of public service as our strongest guarantee of peace—is an objective worthy of our highest American traditions. Interest can be shown in no more effective way than by bringing a new member.

Come, then, see and learn what the latest achievements in Ordnance design are—and there are many—renew again the old interest in Ordnance and its welfare, and thus insure the promotion of those aims for which our Association was founded, "To conserve and extend Ordnance knowledge to the end that our munition power may equal our man power and thereby render our Country an effective factor in keeping the peace of the world."



Editorials

Law—Not War

The National Council for the Prevention of War recently directed a nation-wide demonstration said to have been held in some 2,500 communities throughout forty-four States. The purpose of the demonstration was to crystallize American sentiment in favor of the substitution of law for war, as embodied in the slogan, "Law—not War."

The movement was approved by many of our foremost citizens, including former Supreme Court Justice Clarke, Hamilton Holt, President Lowell, of Harvard University; President David Starr Jordan, of Leland-Stanford University; Governor Baxter, of Maine; Governor Sweet, of Colorado, and many others whose Americanism is unimpeachable and whose soundness of reasoning is quite beyond reproach.

Law—not war, is a commendable move toward molding the public mind to accept the arbitrament of international disputes by reason and justice. It would relegate to the oblivion of the past the old familiar theorem: "Cry Havoc and let slip the dogs of war!" This, we repeat, is a most worthy aim.

Our fear, however, is that too many well-intentioned individuals will see in this slogan a panacea for all international ills, and, unmindful of the course of humanity throughout the centuries, will believe that this catch-phrase will bring about international peace, the goal of poets and of dreamers for ages.

No one is so inhuman as not to hope that this goal will be attained some day, but in the light of experience it is indeed doubtful that such a time is near at hand.

Who can turn through the pages of history and not find that after almost every great upheaval a war-weary people clamored for the outlawry of war, and that scarcely a generation later the peaceful resolutions were forgotten and the old feelings of enmity and hate were enkindled anew?

Law—not war, has been the wish of every reasonable man since the human race first knew the happiness of peace and the horror of armed conflict. And in spite of this yearning there have always been transgressions of rights and neglect of duties which caused even the faintest heart to resort to battle.

We, too, hope that law—*properly sanctioned and guaranteed*—will eventually dethrone the god of war forever; but, until humanity can purge itself of those characteristics that have marked it from the beginning, we suggest that there is far more wisdom—and humanitarianism, if you will—in a policy of justice and right backed by the determination and means to uphold it.

Meanwhile we see little remedy in any formula based on good intentions but lacking those elements of reality without which it cannot be successful.

The American Iron and Steel Institute

Announcement is made elsewhere in this issue that the American Iron and Steel Institute will participate in the Fifth Annual Meeting of the Army Ordnance Association to be held at the Aberdeen Proving Ground, October 26, 1923. It is our purpose to record here our pleasure in having this distinguished organization with us.

The Institute is of venerable lineage. Founded in 1855 as the American Iron Association, it has had a long and useful career. Its Founding Committee summarized its aims "to take all proper measures for advancing the trade in all its branches." With the great advances in the art of steel making the organization became, in 1864, The American Iron and Steel Association, which was merged, in 1913, with the present American Iron and Steel Institute.

Prominent among the first honorary members of more than half-century ago was Captain J. G. Benton, U. S. A., a representative of the Ordnance Department of the Army.

Of the remarkable achievement of the iron and steel industry—particularly in the interests of the national defense—little need be said here; it is a narrative of great accomplishment well known to us all. When our Country and her Allies cried for steel lest they perish, it was the iron and steel industry that put its shoulder to the task, and metal for guns, for ships, for shell, and for armor poured forth in miraculous profusion. It was a Herculean work performed by captains of industry in whose lexicon there is no such word as *fail*.

Speaking at a meeting of the Institute just ten years ago, Mr. James A. Farrell, of the United States Steel Corporation, said:

"The Institute has accomplished a great deal for the general good of the community through the exchange of ideas and information regarding processes of manufacture, of ethical standards, welfare work, and the many other activities connected with an industry so diversified as ours. The progress already made is a guarantee of its continued success, and we should individually and collectively do everything in our power to broaden its scope and develop its sphere of influence."

The participation of the Institute in our next annual meeting, together with its accomplishments of the past decade, is ample evidence that this spirit is still its guiding motive. In participating with us we want the leaders of the great steel industry of America to see what the latest achievements in Ordnance are; we want them to know the latest military uses to which their product is being put; we want them to sense in full measure the great mission of Industrial Preparedness and their intimate relation to it. It will be the endeavor of the Army Ordnance Asso-

ciation to make this meeting not only of pleasant interest to the members of the Institute, but, by so doing, to make it of value to the art of Ordnance and to the National Defense.

The Secretary of War Urges Cooperation

"I cannot let pass this opportunity of asking you in the name of the President and the War Department that you give our plans for industrial mobilization the cooperaton, assistance and support that they must have to be successful, for unless they are successfully carried out the Army of the United States will enter the next war with serious if not fatal shortages in food, clothing and fighting material."—*From an address by the Secretary of War at a luncheon given in his honor by the Commonwealth Club of San Francisco, May 25, 1923.*

Resolutions of the Reserve Officers' Association

Among the pertinent resolutions adopted by the National Council of the Reserve Officers' Association in annual assembly at Indianapolis, Indiana, July 14 and 15, 1923, are several which will elicit the strongest commendation from all citizens interested in adequate national defense.

Action was taken favoring a swift and sure supply of trained personnel for the operation of the Selective Service System in event of emergency, support of the National Guard, the R. O. T. C., and the Citizens' Military Training Camps. Especially noteworthy was the following appreciation of the Regular Army:

"*Whereas* it is the established policy and practice of the War Department to further in every possible way the complete amalgamation of the components of the Army of the United States, fostering in all the essential military virtues of comradeship, teamwork and mutual understanding.

"*Be It Resolved,* that we record our high appreciation of the efficient help that the personnel of the Regular Army has given in the organization and advancement of the citizen components of the Army of the United States; and our confident belief that the War Department will continue to aid, to the full extent of the means at its disposal, the development of the citizen forces."

Here is an expression that will be seconded by all thoughtful citizens. ARMY ORDNANCE adds its unqualified endorsement.

Who's Who in this Issue

This issue of ARMY ORDNANCE is devoted for the most part to automotive development—an extremely important phase of Ordnance.

Major A. B. Quinton, Jr., author of the article on CROSS-COUNTRY CARGO TRANSPORTATION, is Chief of the Tractor and Trailer Section of the Artillery Division, Office of the Chief of Ordnance. His familiarily with the subject and his broad concept of the military requirements for cargo carriers form an authoritative pronouncement on this topic.

Colonel Pliny E. Holt, of the Holt Manufacturing Company, likewise speaks with authority in his paper, DEVELOPMENT OF COMMERCIAL TRACTORS. Colonel Holt has much experience with tractor development, both in a military and commercial capacity; he therefore discusses the subject fully and convincingly.

ARTILLERY DESIGN, by Brigadier General Colden L'H Ruggles, is a complete review of recent progress in artillery development. General Ruggles is Chief of Manufacture of the Ordnance Department and is an authority of world renown.

Mr. Caleb W. Shipley, author of THE TRAILMOBILE UNIVERSAL CHASSIS, is President of the Trailmobile Company of Cincinnati and to him is due much of the credit for the quantity production of trailers by that company during the World War.

Mr. H. E. Howe, Editor of the *Journel of Industrial and Engineering Chemistry,* has contributed a timely discussion in his article, THE ROLE OF CHEMISTRY IN WAR.

The article on GERMAN TANKS is taken from the German work on that subject by R. Kruger, a reliable treatise on the subject. The translation from the German is by Captain William E. Lucas, Jr., U. S. A., of the Tank School, Camp Meade, Maryland.

A. B. Whittet and D. A. Gurney, co-authors of JUMP, are ordnance engineers in the Office of the Chief of Ordnance. Both rank high in their profession. They have written an extremely valuable article on a subject which is certainly more dignified and indeed more important than its name suggests.

Part II of the discussion of TRANSPORT WAGONS FOR MEDIUM AND HEAVY FIELD ARTILLERY, by T. A. Conlon, appears in this issue. Mr. Conlon is an engineer in the Artillery Division of the Ordnance Office who has made an exhaustive study of his subject. Part III will appear in a subsequent issue.

Major Levin H. Campbell, Jr., author of AUTOMOTIVE TESTING, was until recently chief of the Automotive Testing Division at the Aberdeen Proving Ground. He is now stationed at the Rock Island Arsenal.

An unique invention is described by Mr. William A. Twamley in his article on THE CAMPBELL-TWAMLEY DYNAMOMETER. Mr. Twamley is an automotive engineer on the staff at the Aberdeen Proving Ground.

Major Glenn P. Wilhelm, Chief of the Small Arms Division of the Technical Staff, Office of the Chief of Ordnance, completes in this number his very thorough review of the TESTING OF SMALL ARMS AND AMMUNITION.

Major J. E. Munroe, author of SPRING RETURN VERSUS RECUPERATOR, presents a convincing treatment of a subject that will bear further discussion. Major Munroe is stationed at the Rock Island Arsenal where his theories on the subject have ample opportunity for practical demonstration.

Election of Officers

In accordance with the provisions of the Constitution and By-Laws of the Army Ordnance Association, a nominating committee composed of General James A. Drain, Chairman, and Messrs. A. Y. Leach, Jr., H. C. Sheridan, Howard Bruce, and C. C. Sheppard, has recommended the following officers for re-election: to serve until October, 1924, for President, Mr. Benedict Crowell; for Vice President, Mr. William W. Coleman; to serve until October, 1925, Directors, General Guy E. Tripp, General Samuel McRoberts and Mr. Waldo C. Bryant. Ballots are now being sent to members. All are requested to return them to the Secretary as soon as possible.

Cross-Country Cargo Transportation

By

A. B. QUINTON, JR.

THE extensive use made of motorized equipment, such as tractors, tanks, and trucks, during the World War, and the still further broadened use of these vehicles now contemplated has emphasized the importance, and, in fact, the necessity of providing improved means of furnishing supplies to the several arms of the service equipped largely with motor vehicles capable of extensive movement across country. The war in France developed certain needs, and when consideration is given to the possibility of waging war in countries less adequately equipped with good roads than France, the necessity of furnishing cargo-carrying vehicles for use over poor roads and across country is apparent.

Major A. B. Quinton, Jr.

Troops advancing over difficult ground removed from good roads, or roads of any description, must be furnished ammunition, food, water, and other auxiliary supplies, if the advance is not to be interrupted, and too much importance cannot be attached to the necessity of selecting proper types of vehicles for this duty.

A considerable amount of thought has been given this problem by the Ordnance Department during the past four years, and it is of interest at this time to present a résumé of the work which has been done. This work, considered in relation to the requirements for cross-country cargo vehicles of the various using services, will lead the way to the particular types of vehicles which would be selected for use immediately in the event of an emergency, and further, would outline any special development which must be undertaken for the final solution of the problem.

Before a selection can be made of the most suitable type of cross-country cargo vehicle, it is necessary to consider first the kind of supplies to be transported for the use of the several services, and next to determine for each service the degree of cross-country mobility required.

For both the Field Artillery and Infantry Arms, the supplies considered may be summed up in general as all those which are normally carried with the Division. Such supplies include ammunition, rations, baggage, communications equipment, combat supplies, water, gas, oil, tools and repair parts. With the exception of the field artillery ammunition, practically all of these supplies are now carried in the animal-drawn escort wagon of approximately 3,000 pounds capacity, and for reasons primarily tactical, it is desirable to retain this capacity of 1½ tons in any type of vehicle which may be adopted. With the great variance, however, in the heaviness of the different supplies, it will probably be necessary to mount several different types of bodies to accommodate economically the several classes of supplies, but a strict observance must be given to the requirement of reducing to a minimum the number of these special bodies.

The cross country mobility of the 1½-ton cargo vehicle must be at least equal, and preferably exceed, that of the animal-drawn escort wagon or caisson and limber, and its economical movement on roads is imperative. The specifications cited above as regards capacity and mobility of a cross-country cargo vehicle should be satisfactory for the army at large, except for tank units, the requirements for which differ materially from those of the other services, and hence, present a separate problem. In addition to the supplies enumerated above, tank units have to be furnished large quantities of gas and oil and also have a particularly heavy load consisting of repair facilities. This makes it impracticable for them to utilize the 1½-ton vehicle which is satisfactory for the remainder of the army. A careful study made by the personnel of tank organizations discloses the fact that a cargo capacity of approximately 5 tons is best suited to the needs of tank supply and maintenance, and it is believed that every attempt should be made to furnish a satisfactory cross-country vehicle of this type and capacity.

Furthermore, the tactical employment of tanks demands the maximum of mobility in the supply vehicle for the reason that the tank is not permitted to move to the rear for replenishment of gas and oil and for minor repairs, thus imposing upon the supply vehicle the duty of negotiating the most difficult kind of terrain, indeed the same terrain as that covered by tanks in combat. A degree of mobility similar to that of the 6-ton tank, namely, ability to cantilever 3-foot trenches and to mount vertical obstacles 3 feet in height, is believed to be necessary.

Before making a choice of the proper type of vehicle for the use of any branch of the army, it will be well to consider the methods now available, and those which can be made readily available, to accomplish satisfactorily the cross-country transportation of heavy cargo. In general,

three are three methods, which will be discussed as follows:

A. Tractors, wheeled or track-laying, drawing trailers, wheeled or track-laying.

B. Trucks with track-laying adapters.

C. Tractor caissons, wheeled or track-laying.

A. Tractor and Trailer

Considering the tractor and trailer method of transport, attention is called to the development now under way aiming toward the selection of a suitable tractor for drawing artillery matériel. It is quite certain that a suitable tractor will be found, one either produced commercially or of special design, for adoption as a standard vehicle in service, and serious consideration should be given to the use of this vehicle for general cargo work. It is reasonable to presume that the artillery tractor, which is required to haul the divisional field piece over extremely rugged terrain, will be capable also of drawing over the same ground a cargo vehicle of a weight equivalent to that of the 75-mm. gun and carriage. In fact, it is probable that the divisional artillery tractor adopted will be capable of drawing a trailed load of approximately 5,000 pounds. With the exception of tank supply, this tractor and trailer mode of cross-country transportation will undoubtedly be

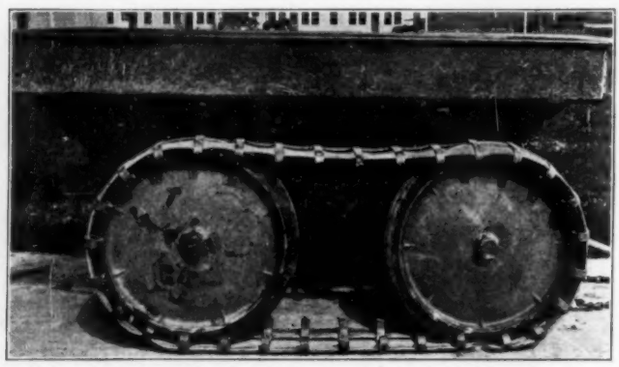


Fig. 1. Three-quarter ton Trailer

satisfactory as concerns cross-country performance, but the disadvantage of this method lies in the uncertain durability which the equipment would have if forced to travel for long periods over hard surface roads, although this disadvantage would be minimized if the selection of the artillery tractor favors the wheeled rather than the track-laying type. It is definitely known at this stage of the development of tracks for vehicles of any description that the life of the track, when traveling on hard roads, is relatively short. The principle should be accepted that, while the normal use of track-laying vehicles, both the tractor and trailer, will be the same as that of our present horse-drawn transport in accompanying the movement of troops on roads, their lives should, in the case of the lighter vehicles, be conserved by their transportation in motor trucks.

The tractor and trailer mode of transportation recommends itself primarily on account of the fact that both the tractor and the trailer of proper capacity are produced commercially, and the difficulty of securing an adequate supply at the start of an emergency is minimized. In fact, this is the only means which would be readily available in the event of war, and its adoption for the army at large, the tank units being the only exception, is forced upon us.

B. Truck With Adapter

In considering the commercial truck with adapter as a means of cross-country transport, it is assumed that the vehicle itself would be of a standard type universally used throughout the army for road work, the only major change being the addition of the adapter to replace the rear wheels for the improvement of its cross-country mobility. Among the minor modifications which would have to be incorporated in the truck are: a greater reduction of the final drive and an increase in the cooling capacity of the motor. The question of the permanency of the adapter attachment of the truck is a matter of prime importance, because if the attachment is of the removable kind, the truck, when traveling on good roads, will have the same performance as that of the ordinary road vehicle, and if the adapter can be applied quickly and with same, the vehicle can operate satisfactorily across country, this would appear to be the ideal method in respect to performance. An adapter permanently fixed to the truck will undoubtedly assure better cross-country performance than that of the detachable type. On the other hand, when used over hard surface roads, its life would be indeterminate, in which respect it is not unlike the track-laying type of tractor.

Even if the cross-country performance of the truck with adapter were all that it should be, its adoption as a type could not follow because such vehicles are not produced commercially. It is agreed by all that a delay could not be tolerated in securing cross-country vehicles for use in the beginning of an emergency. It may sound very simple to speak of manufacturing adapter attachments and modifying the final drive reduction and cooling system of a standard truck, but the fact of the matter is that in the great rush of war work, the so-called minor changes approach a considerable magnitude, and the truck with adapter is immediately thrown into the class of special vehicles, and no reliance can be placed upon their production during the first year of an emergency.

C. Tractor Caisson

The tractor caisson as a type having adequate cross-country ability is not produced commercially, hence, it is the best example which can be given of the special type vehicle. Consequently, in the proving of the design, development of manufacturing methods and tooling-up for production, the possibility of securing in adequate quantities until the beginning of the second year of any future emergency is precluded. Considering cross-country performance only, the track-laying tractor caisson is the ideal type of vehicle. On the other hand, the durability of the vehicle, when traveling on hard surface roads, is subject to the same uncertainty as the track-laying tractor.

Coming now to the selection of the appropriate types of vehicles for the several services, it is found that the problem resolves itself in two phases, namely:

A. *Immediate Solution.* The adaptation of commercial types and standard types now in service to meet army needs to the greatest degree practicable.

B. *Final Solution.* Development and production in quantity of such ideal army transport as may be found possible and of sufficient advantage to warrant its adoption.

Immediate Solution

For the army at large, with the exception of tank units, the tractor and trailer mode of transport should be selected for the reasons which have been discussed and which may be summarized briefly as follows: both units are produced commercially, and consequently are readily procurable; the adaptation to cargo transport of the same vehicle which will be standard for other uses, namely, the divisional artillery tractor and trailers which may be modifications of the standard artillery ammunition transport vehicle, thus

reducing the number of types to be procured and maintained.

As stated above, a program is now under way covering the procurement and test of the most promising types of commercial tractors of both the wheeled and track-laying types. This program will of necessity be of a continuing nature, in order that the list of acceptable vehicles may always be kept up to date, thus insuring no indecision on the part of the War Department in selecting the best vehicle for procurement in the event of war. Practically all of the work to date on the ammunition and cargo trailer has been confined to the development of the special track-laying type, but a program should be inaugurated similar to that now under way pertaining to artillery tractors, which will permit of the selection from the commercial field of trailers readily procurable and best suited to the military needs. This program covering the test of commercial trailers should also be made continuous.

The immediate solution for the supply of tank units cannot be solved quite as satisfactorily. When proper consideration is given to the requirements as to mobility and performance for the supply of tank units in the most advanced areas, it will be found that the mode of transport selected for the army at large and all other modes of commercial cross-country transportation are inadequate and wholly unsuited to tank unit needs. Having arrived at this conclusion, the need for the development of special means of transportation for tanks, is emphasized, and until the development of this special means is accomplished, such improvised means as hauling supplies on sleds drawn by tanks will have to be used.

Final Solution

Considering first the tank problem, which is the most pressing, it is believed that steps should be undertaken immediately to design, construct and test pilot vehicles of the track-laying tractor caisson type, having a capacity of approximately 5 tons and cross-country mobility equivalent to that of the 6-ton tank.

With regard to the remainder of the army, the mode of cross-country cargo transportation selected as an immediate solution cannot be considered as wholly ideal. Therefore, it is thought that first consideration should be given to the use of the best commercial vehicles supplemented by modifications and improvements; and that the demand for vehicles of special desgin be anticipated by carrying on adequate studies to facilitate the production of special types when demanded.

Commercial Prospects

The statement has been made that such and such a type of vehicle is or is not in commercial production, and that this has been the influencing factor in the selection of types for adoption. On account of this commercial aspect it may be of interest to discuss the probable future commercial development. First and last, commercial production is a dollar and cents proposition. There cannot be any subsidy for vehicle manufacture to meet army requirements, although manufacturers have without exception shown the greatest willingness to cooperate with the War Department, with a view to incorporating in the commercial design such features as are not inconsistent with the commercial demand and which will not affect adversely the cost of the product in competition with others of similar value and utility. Such cooperation is beneficial, of course, but it does not go the whole way. Granting that a commercial demand does exist for vehicles for use in the mining districts, oil fields, lumber regions, etc., requiring cross-country performance almost as extreme as that demanded in a military vehicle for the supply of tank units, yet in the present stage of the development, the commercial producer does not feel that he can furnish a product sufficiently satisfactory to guarantee the proper return on money invested. Commercial development will be followed very closely, and any change in the situation will be welcomed; but those who have given proper study to the subject are more or less unanimous in the opinion that for the ideal cross-country transportation vehicle, main reliance will have to be placed on the existing War Department agencies for this development.

Vehicles Considered for Test by the Ordnance Department

During the past four years, the Ordnance Department has been very actively engaged in the design, manufacture and test of automotive vehicles, some of which may be classified as *special,* while others are *commercial* in character. There are listed below all of the vehicles which have been under development, and while it will be noted that some of them are not specifically adapted to cross-country cargo transportation, they are closely related to this problem because of the similar engineering principles involved in their design.

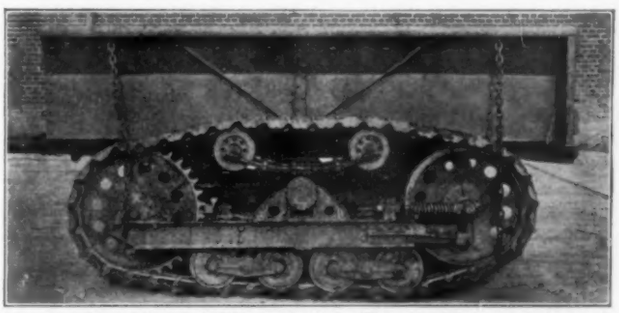


Fig. 2. One and one-half ton Trailer (Heavy), Watertown Arsenal

A. Power Carts
1. Syracuse type.
2. Peoria type.
3. 600-lb.—Model 1922.
4. 900-lb.—Model 1922.

B. Reconnaissance Tractors
1. Syracuse type—air-cooled motor.
2. Peoria type—air-cooled motor.
3. Peoria type—water-cooled motor.
4. 800-lb.—Model 1922.
5. 1600-lb.—Model 1922.

C. Artillery Tractors (Special Ordnance Design)
1. 2½-ton—Model 1918.
2. ½-ton—Model 1918 (modified to install Class B truck engine).
3. ½-ton—Model 1918 (modified to improve cooling system of Cadillac engine).
4. Divisional Tractor—Model 1920.
5. Divisional Tractor—Model 1920 (modified).
6. Corps Tractor—Model 1921 (under construction).
7. Army Tractor—Model 1920.
8. Army Tractor—Model 1922 (under construction).
9. Motor Carriage, Mark IV A.

D. Tractors (Commercial)
1. Fordson with regular equipment.
2. Fordson with P. T. wheels.
3. Fordson with Bates Adapter.
4. Fordson with Hadfield-Penfield Adapter.

5. Holt, T-30.
6. Holt, T-35.
7. Best, 30.
8. Pavesi.
9. Topp-Stewart.

E. Modified Trucks

1. Ford, with Chase Track.
2. Dodge, with Chase Track (fabric, 8 wheels).
3. Dodge, with Chase Track (fabric, 6 wheels).
4. Dodge, with Chase Track (cable, 8 wheels).
5. Dodge, with Chase Track (cable, 6 wheels).
6. Mack-Roadless, 2½-ton.
7. Militor, with Chase Track (cable, 8 wheels).
8. Militor, with Chase Track (cable, 6 wheels).
9. Mack-Christie (this has not been submitted to Ordnance Department for test).
10. Kegresse-Hinstin Adapters.
11. Ball Truk-Trak Adapter.

F. Trailers

Hand Carts:

1. Syracuse Model.
2. Ammunition Hand Cart, Model 1922.
3. Gun Hand Cart, Model 1922.

Trailer Caissons:

1. ¾-ton, Model 1921.
2. 1½-ton, Wagon type, Model 1920.
3. 1½-ton, Cart type, heavy.
4. 1½-ton, Cart type, light.
5. 3-ton, Cart type, track-laying.
6. 3-ton, Convertible.

G. Tractor Caissons

1. Mark VII.
2. Mark VIII.

H. Motor Carriages and Accessories

1. Mark VII.
2. Mark VI.
3. Christie for 75-mm. Gun—105-mm. Howitzer, Model 1920.
4. Mark II.
5. Christie for 155-mm.—8-inch Howitzer.
6. Model 1922 for 4.7-inch Gun, Model 1920 MI.
7. Mark II.
8. Mark III.
9. Mark III—MI.
10. Mark I.
11. Caterpillar adapter for 8-inch Howitzer Carriage, Mark VII.
12. Caterpillar adapter for 155-mm. Gun Carriage, Model 1918.

It is not feasible to give here a complete detailed account of the tests which have been conducted on all of the vehicles itemized above, but a résumé follows, in which there are shown pertinent features developed in the tests as related to the cross-country transportation problem.

¾-Ton Trailer Caisson, Model 1921

Two of these trailers were designed and manufactured by the Ordnance Department and delivered to the Aberdeen Proving Ground for test December, 1921. The main characteristics of the vehicle are steel cargo body spring mounted on two axles, which are constructed mainly from standard Dodge car parts; a Chase fabric track is mounted over two solid rubber-tired wheels on each side of the trailer; weight of trailer unloaded 1425 pounds. One trailer was towed a distance of 740 miles and the other 567 miles over standard test roads, the majority of the run being made on unimproved dirt roads. The towing vehicles used in the test were the 75-mm. Gun—105-mm. Howitzer Motor Carriage, Mark VI, the 2½-ton Divisional Artillery Tractor, Model 1920, and 2½-ton Tractor, Model 1918 with Class B Motor, and the T-30 Holt Tractor.

The trailer loaded to its normal capacity of 1500 pounds was maneuvered over extremely rugged terrain, and no defects of any importance were noted except that the brakes were found to be of inadequate holding power. In running along the side of a 30° slope covered with about six inches

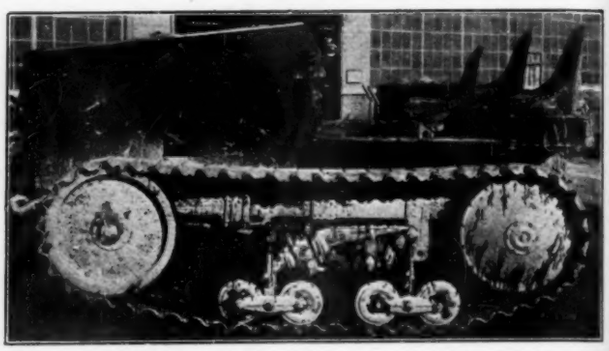


Fig. 3. Two and one-half ton Trailer (Heavy), Watertown Arsenal

of wet grass, there was no tendency to side-slip, and it was found that the trailer could cross ditches and broken ground with equal facility. The vehicle could be turned through an 18-foot circle over sand, soft mud, cinders, broken stone, dry earth and concrete without difficulty of any kind. The track was not thrown or broken during any of these tests. Ten or fifteen circles of this kind were made over each of the different types of ground referred to, and because of the flexibility the track unloaded with ease any soil or stone that was drawn into it.

During the total mileage run on both trailers, the tracks wore very well. The metal lacing couplings were broken frequently, the eyes in the lacing tearing through and releasing the securing pin. Little or no trouble was experienced with the fabric belting. The track links wore considerably and several of them broke, and it is evident that they would not last for more than a total of 1,000 miles.

At the end of the run, the wheels and bearings were in excellent condition and the solid tires were worn slightly, the rear tires being worn more than the front tires. No trouble was encountered with the axles, main frame, brake rigging, or track adjusting feature of the main frame.

The conclusions drawn by the Proof Officer were to the effect:

(a) That this trailer is a decided improvement on the wheeled type vehicle as it can negotiate with apparent ease any character of terrain or condition of soil ordinarily encountered in service. It is compact and in congested spaces can be easily managed.

(b) That the track with a few minor improvements would be admirably suited for this type of vehicle.

(c) That the brakes are inadequate and the brake lever inaccessible to the operator.

(d) That the lunette spring and draw bar end are not sufficiently strong.

(e) That the main frame, axles, wheels, and adjusting mechanism are satisfactory.

(f) That the body can carry the intended load, and when used to transport personnel, can accommodate ten men comfortably.

(g) That the springs are not sufficiently strong to support the normal load of 1500 pounds.

The metal cargo body is of a type which permits floating of the entire vehicle with its normal load. In this particular vehicle, it was not necessary to go to any extreme measures to provide for floating. In any further design, in case complications should arise through the requirement of providing a floating body, consideration should be given to the necessity of the requirement. (See Fig. 1.)

The entire run noted above was with the Chase track in place. When used without track and running on the solid rubber tires, this trailer should be as satisfactory as any of the commercial types on the market, the life of which is many thousand miles. Since the wheel and axle parts are of standard Dodge construction, the running gear should be able to stand up under the maximum towing speeds which might be encountered in service without any difficulty.

Trailers for Divisional Artillery

The 1½-Ton Cart Type, Light (Watertown Arsenal); 1½-Ton Cart Type, Heavy (Watertown Arsenal); 1½-Ton Wagon type (Cleveland), were manufactured and tested in accordance with the recommendation of the Caliber Board for the transport of artillery ammunition in the Division. The characteristics of the two Watertown vehicles, light and heavy, are quite similar, but by special effort a reduction of about 900 pounds was made in the case of the light type, the latter vehicle weighing 3800 pounds without load, while the heavy type weighs 4700 pounds. The 1½-ton trailer, Cleveland type, weighs 4115 pounds unloaded.

The bodies of these trailers are considerably larger than are necessary to carry their normal rated load of 3,000 pounds of artillery ammunition, and for artillery work this may be a disadvantage on account of the likelihood of overloading. On the other hand, for general cargo work, the bodies are particularly well adapted on account of this capacity.

The vehicles are special in construction, although utilization has been made of track rollers, idlers, track shoes, pins, etc., which are standard for the experimental 2½-ton tractor, Model 1920, and in the case of the trailer of Cleveland design the spring suspension in its entirety is identical to that of the above mentioned tractor before the latter was modified, but the redesigned parts of the tractor could be applied to this trailer without change.

The tracks on all three of these trailers are of a design identical to that used on the 2½-ton Divisional Tractor, Model 1920, before its modification. By reference to the proof reports, it will be seen that these tracks failed primarily because of the insecure method of fastening the track pins although other defects were present. In this connection, it should be noted that an improved type of track for the tractor has been manufactured and has now been running under test for something over 1,200 miles with very little wear shown to date, and this track could be put on any or all of the trailers and the same satisfactory performance would be assured. In fact, at the present time in the continuation of the test of the 1½-ton trailer, Watertown type, a new track of latest design has been installed.

The mileage shown on the three trailers at the Proving Ground was determined almost entirely by the wearing out of the track due to the defects noted above. Had the new track been available, it would have been possible to continue the test further, and in case it is decided that any further work is to be done with these trailers, the manufacture of new tracks will be recommended.

The actual mileage which was run and which determined the life of the old style track was:

(a) 1½-ton Watertown Light, a distance of 284 miles, of which 106 miles was with the normal load of 3,000 pounds, and 91 miles with an overload of 50 per cent, or a total of 4,500 pounds, and 87 miles with a 50 per cent or 1,500 pound load.

(b) 1½-ton Watertown Heavy (Fig. 2), a distance of 309 miles, of which 228 miles was with its normal load of 3,000 pounds, and 81 miles with an overload of 50 per cent or 4,500 pounds.

(c) In the case of the 1½-ton Cleveland trailer, a distance of 424 miles was shown prior to the receipt of the vehicle at the Aberdeen Proving Ground, after which a run of 65 miles was made.

An examination of the vehicles will show that as track-laying trailers, there is a minimum of unsprung weight for this type of conventional caterpillar construction, and in fact, it is not believed that the unsprung weight could be materially reduced in any redesign.

These trailers can be towed across ditches with steep banks without difficulty. The facility of running up slopes is dependent entirely upon the power of the towing vehicle, but it has been determined that there is a marked difference in the ease with which any tractor can tow the trailers

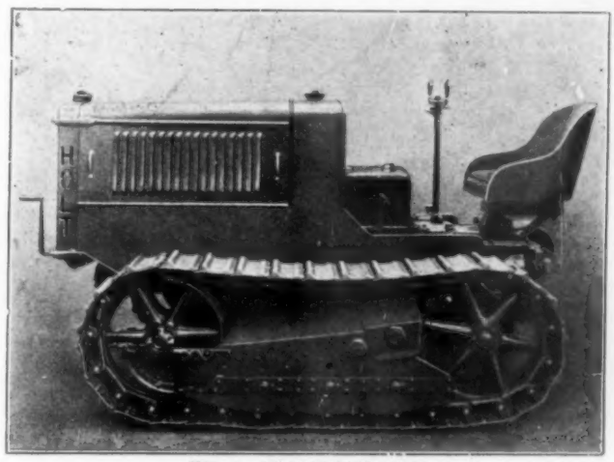


Fig. 4. Holt T-35 Tractor

of varying weight, the advantage, of course, being in favor of the lighter vehicle. In the case of the 1½-ton trailer heavy, the limiting slope forward was found to be 35° when towed by the 2½-ton tractor, Model 1918, with Class B motor.

There is a decided tendency in all these trailers to slip laterally when being towed on side slopes of more than 25 per cent grade, trailers loaded to their normal capacity, condition of ground being soft and covered with turf. In this connection, it must be remembered that a 25 per cent side slope is quite extreme, and it is seldom that a vehicle would ever be called upon to negotiate such a slope where any choice of route can be made.

In reference to the turning radius of the various tractors, no minimum radius can be quoted, as this is dependent solely upon the radius of turning of the towing vehicle. When towed behind a tractor which turns as sharply as possible without engaging the front corners of the trailer body with the sides of the tractor, the turning radius of the trailer is practically zero.

In reference to the loading of the track, it may be stated in the case of the Watertown trailers when turned in ground covered with loose broken stone and cinders, the track became badly loaded and on starting ahead the inside track was quite apt to become locked. When locked, the

truck rollers and rear idlers in rolling over the loaded portion of the track cause the semi-elliptic spring, which carries the track supporting rollers, to compress, thereby permitting a lengthening of the track, but in this case on account of the poor engagement of the rollers and idler with the track, derailment is apt to occur. This same fault was encountered in the 2½-ton tractor, Model 1920, prior to its redesign, but after strengthening the cross-springs, to which the track rollers are attached, the flexibility has been decreased to some extent and no tendency to derail has developed. It can be presumed that if this redesigned type of suspension were added to the trailer it would perform as satisfactorily as it has on the Divisional Tractor.

It is very gratifying to note that in the case of the Cleveland type trailer, the draw-bar gave absolutely no

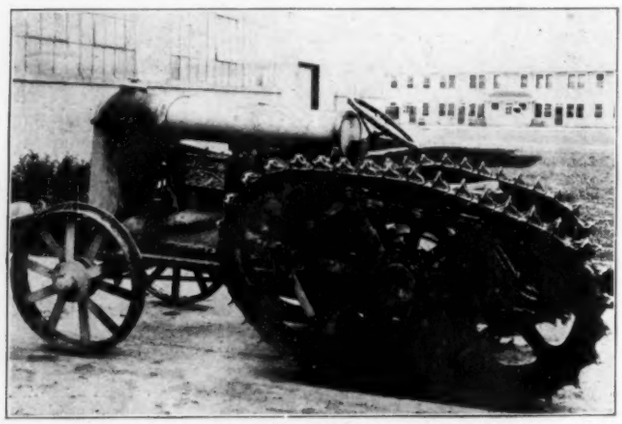


Fig. 5. Fordson Tractor with Hadfield-Penfield Adapter. (Left track frame inverted.)

trouble in any feature of the test. On any trailer the draw-bar design has been found to be particularly difficult, but apparently a solution has been found at least for vehicles of this weight in the design as used for the Cleveland type.

Divisional Artillery Tractor, Model 1920

This tractor offers such a radical departure in design from that of previous models and from conventional commercial tractors that it is appropriate to cite its main characteristics (see Fig. 3), which are as follows:

(*a*) Length over all ---------- 128 inches
Width over all ---------- 60 inches
Weight ---------- 7285 lbs.

(*b*) The vehicle is of the track-laying type. Its weight is carried by 4 track rollers on each side. The track rollers are rubber-cored to absorb some of the road shock.

(*c*) The main frame is suspended from the track rollers by means of two semi-elliptic leaf springs on each side. These springs are arranged to give maximum rigidity against lateral displacement of the track rollers.

(*d*) The front idlers are rubber-tired and are mounted on swinging arms which project forward from the front axle. These arms are able to pivot about the front axle, and are sprung by quarter-elliptic leaf springs.

(*e*) The transmission is different from the conventional design, in that a double clutch is provided in connection with the gear set which permits of two speeds with each gear position, by merely disengaging and engaging the double clutch. There are thus four speeds forward and two speeds reverse, with two gear shifts forward and one gear shift reverse.

(*f*) The rear axle is of the internal gear drive type. The drive from the transmission clutch shaft is transmitted through independent trains of gears to the left and right drive sprockets.

(*g*) The track differs in shape from the conventional design in that the pads are formed with large scooped-shaped recesses on each side which have the effect of cupping the soil and increasing the traction. A smooth surface is presented for operation on hard ground. The entire tractor is of unit construction. All units are mounted on the main frame as to be readily removed as a unit.

(*h*) The engine used is a White 8 or 16-valve truck engine, both types having been used in the two tractors built.

Two of these vehicles were constructed and received a preliminary test at the Aberdeen Proving Ground, after which one was sent to Fort Bragg for test by the Field Artillery Board.

As to performance, it may be stated that this vehicle will haul its rated load, consisting of the Divisional Gun Carriage and Limber, over practically any kind of terrain which would nominally be encountered in the movement of artillery. This tractor has been found able to draw its rated load over good roads at the maximum speed for which it was designed, namely, 12 miles per hour.

One of the pilot vehicles has been run under test a distance of 1,200 miles, of which 800 miles was run at the Aberdeen Proving Ground, and only minor mechanical troubles developed during the test. With field repairs only, it is estimated that the life of this tractor should exceed 3,000 miles, which was set as a practical limit in the design of the vehicle.

With respect to the performance of certain parts of this tractor, the Proof Officer reports as follows:

> "The track adapts itself easily to irregularities of the ground and crosses such irregularities with very slight shock but with a considerable tendency to pitch. The pitching, however, is not so extreme as to affect the ability of the vehicle to accomplish its mission. Rubber inserts provided in track rollers and rubber tires on idlers reduce noise of operation. No replacement required or excessive wear noted after 800 miles' operation. * * *
>
> "The double-clutch transmission by which two equal speeds forward, or different speeds forward for turning, can be obtained with each gear position worked satisfactorily. The steering control by two levers occasioned some objection at first, but familiarity with the control has overcome this objection.
>
> "The spring suspension has performed satisfactorily. At no time during the approximate 1,200 miles of operation were the tracks thrown off of the truck wheels. The construction of the running gear is such that the track can follow the contour of the ground very readily."

Holt T-35 Tractor

The Holt T-35 tractor is produced in quantity commercially and is of such improved design over that of earlier models of commercial tractors that its satisfactory performance is assured. (See Fig. 4.)

The engine and transmission complete are carried in the rear by a pivot shaft or tube running through the trans-

mission case, resting on a large rubber pad on the truck frame, and hinged to the trucks in front of the shaft or tube.

The front end of the engine and transmission is supported by a cross-leaf spring, which pivots at its center on a pin secured in the lower crank case of the motor directly under the main center bearing.

The engine is a Hall-Scott engine with overhead valves (set on an angle), overhead camshaft, and spherical shaped combustion chamber.

General dimensions of tractor:

Length over all	103 inches
Height to top of hood	52 inches
Width over all	48 inches
Clearance between tracks	28 inches
Clearance under engine	11 inches
Width of track	10 inches
Weight (without driver)	4150 lbs.
Motor	4″ x 5½″

Speeds (with motor at 1,000 r. p. m.)
Forward: Low, 2⅛ m.p.h.; intermediate, 3 m.p.h.; high, 5¼ m.p.h.

In a test of 1,017 miles at the Aberdeen Proving Ground the following pertinent facts in regard to its performance are shown:

The greatest slope ascended or descended was 35 degrees. The tractor showed no tendency to tip over.

It is thought that it could ascend or descend on slopes of 40 degrees to 45 degrees without tipping over. On ascending a slope of 35 degrees the tractor easily pulled a 75 mm. gun in low speed.

On descending a slope of 35 degrees with a load the tractor was not heavy enough to hold the load back and the tractor was pushed around cross-ways in the road. In descending slopes with a load it is necessary that brakes be set on the wheels of the load.

The tractor was operated on side slopes up to 35 degrees. It showed no tendency to turn over.

The tractor was run for 15 minutes in each of the following positions: Front end elevated to about 40 degrees; rear end elevated to about 40 degrees; on side slope at about 35 degrees.

The engine functioned normally in all positions. The front spark plug became fouled when operating with the rear end elevated.

The tractor will cantilever a distance of 26 inches going either forward or backward. Going forward it will bridge a distance of 30 inches, going backward will bridge a distance of 27 inches.

Turning test: On concrete, dirt, normal soil, gravel, sand, and mud the tractor will turn about one track as a center in 3 speeds forward and in reverse, either to left or to the right.

In mud or sand the tractor was turned until mud or sand was loaded on the track. The tractor was then run forward. The mud and sand did not interfere with the operation of the tracks.

This was repeated in crushed stone. When the tractor was started forward the stone got between the track to jack-knife.

The tractor can easily pull divisional artillery through any kind of soil, provided the tracks can get traction.

The motor, transmission, clutches and final drive are satisfactory.

The closures for truck rollers are ineffective. There are no effective closures on the market today.

In conclusion, it may be stated that this tractor has a mileage life of 1,000 miles without major repairs or replacements, and as such is highly satisfactory for use as the Divisional Artillery tractor.

Fordson Tractor with Hadfield-Penfield Adapter

When consideration was first given to the test of the Fordson tractor, it was decided that the rear wheels of the vehicle should be replaced by some form of commercial adapter which would insure better tractive effort of the machine, and in addition minimize the danger of overturning. Consequently, two types of adapters, the Bates and the Hadfield-Penfield, were procured and assembled to the Fordson tractors for test. In addition to these two adapters, a set of P. T. wheels was procured and tested, and while the substitution of this equipment does not obviate the overturning danger, it was the claim that the wheels would increase the tractive effort of the vehicle. (See Fig. 5.)

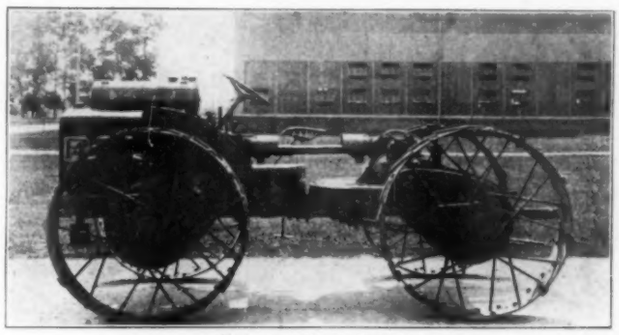


Fig. 6. Pavesi Tractor

As compared to the special Divisional tractors which have been under development by the Ordnance Department, the Fordson tractor develops approximately one-half the draw-bar pull, and it was, therefore, agreed that instead of attempting to haul the normal Divisional load of gun and limber, an attempt would be made only to haul a single load, although the preliminary tests with both the Bates and Hadfield-Penfield adapters were with the 75 mm. Gun Carriage Model 1916, with limber, a total load of 4,569 pounds. It may be definitely stated, however, that a maximum load of 3,000 pounds is all which the Fordson tractor can be relied upon to handle over extremely rugged ground.

The ground clearance of the Fordson tractor is relatively low, approximately 9 inches, as compared with the clearance of 14 to 16 inches which it has been the endeavor to obtain in vehicles of special design. This condition is inherent in the construction of the vehicle and cannot be improved. When the tractor is used with the Hadfield-Penfield adapter, which extends considerably to the rear of the tractor axle housing, it is necessary to use a special hitch which extends the pintle to the rear, to prevent interference with the adapter tracks and to raise the pintle to a sufficient height. The height of the pintle has been extended to a point which leaves a small margin of safety in the overturning moment produced in draft.

The test of the Fordson equipment with adapters to date has shown that the limiting component in the life of the vehicle is the special adapter used. In fact, in summarizing the tests of all the Fordson vehicles which have been used with the special adapters, very little difficulty has been experienced with the tractor proper. Practically the only part of the vehicle which might be considered unsatisfactory is the frail front wheel, the life of which is quite

indeterminate. It is indeterminate in that its life is dependent almost entirely upon the character of service to which the vehicle is put. When used over hard concrete roads, the front wheels are deformed badly in a short time. Commercial front wheels made by the Whitehead & Kales Company have been procured and added to the Fordson tractors under test, and it may be safely said that these solid rubber-tired wheels will stand up during the entire life of the tractor.

The road testing of the Fordson tractor with Hadfield-Penfield adapter extended over the period from July 25 to September 6, 1922, in all kinds of weather and conditions of roads. During this period the vehicle was actually road tested thirty-one days and was in the shop for repairs a portion of two days. For the remaining period

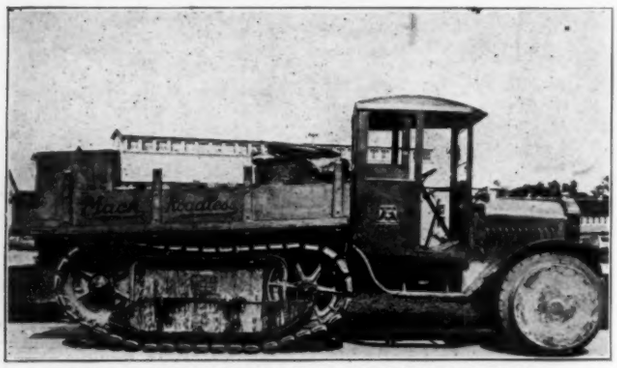


Fig. 7. Two and one-half ton Mack Roadless Truck

it did not leave the shop because of lack of personnel or for some other reason not connected with the failure of the vehicle. During this period of testing, a total of twenty-five man hours was spent in maintaining and repairing the adapter. No difficulty of any consequence was had with the Fordson tractor proper.

As a result of this preliminary test at the Proving Ground, four additional tractors with Hadfield-Penfield adapters were procured and sent to Fort Bragg for test by the Field Artillery Board. While no official report has been received from the Artillery Board covering the performance of this equipment under test, it has been observed by the personnel of the Ordnance Office that the tractors are performing quite satisfactorily. It is unfortunate that the test of the Fordson tractor has been confined entirely to the draft of artillery matériel rather than to the hauling of cargo trailers, but in this connection it is reasonable to presume that the tractor could haul a wheeled trailer of a weight not exceeding 3,000 pounds with equal facility. The performance of this tractor in towing a track-laying trailer could only be determined by actual test, and the degree of success which might be obtained would be in direct proportion to the weight of the trailer and the resistance offered to traction of the track mechanism.

Pavesi Tractor

The Pavesi P-4 tractor is of Italian design and manufacture, and it was purchased for test because of its interesting characteristics as revealed in a motion picture reel which was exhibited to the personnel of the Ordnance Department and the interested services. (See Fig. 6.)

It is a four-wheel-drive tractor, with a horizontal opposed, two-cylinder engine with 5⅛-inch bore and 7⅛-inch stroke. The power is transmitted to the wheels through axles that turn concurrently through equal angles in steering, thus eliminating the necessity for a differential in the drive between the two axles. This concurrent steering of the axles is accomplished by building the tractor in two sections, and joining them together, by means of a seamless tube, with a curved rack on each engaging a pinion on the tube, so that when the front axle is turned to the left the rear axle is turned to the right through an equal angle. There is a differential in the drive between each pair of wheels, and universal joints in the shaft connecting the two transmissions. The final drive is by means of chains which are well housed.

The flexibility of the tractor is remarkable as it is arranged so that the planes of one axle can assume considerable angularity to the other which permits the four wheels to be in contact with the ground on extremely uneven ground.

General Dimensions and Weights:

Overall length	11′ 10″
Overall width	6′ 4″
Overall height	5′ 6″
Length of wheel base	6′ 8″
Ground clearance	1′ 10″
Center to center of wheels (tread)	4′ 10″
Diameter of tires	42″
Width of tires	10″
Height of grousers	2″
Weight, complete	6400 lbs.

Road Speed:

On concrete: High gear, forward and reverse	6.39 mph.
On concrete: Low gear, forward and reverse	3.09 mph.
On dirt road: High gear, forward and reverse	5.25 mph.
On dirt road: Low gear, forward and reverse	2.84 mph.

Of the total distance of 276 miles which this tractor has run under test, 178 miles were run with the tractor towing a 4.7-inch Gun Carriage, Model 1916, weighing 7,420 pounds, and its limber, weighing 1,545 pounds, total weight 8,965 pounds. This run was accomplished in 50.51 hours, which represents an average speed of 3.53 miles per hour.

On one occasion in drawing this matériel through a swampy area, the tractor became stalled when the wheels turned without securing traction. However, the records show that all track-laying types of tractors have also become stalled when drawing their rated loads through the same area.

The engine in this tractor is not powerful enough to develop the full traction on grades, but otherwise it is a very interesting and promising type of wheeled tractor. However, it is of foreign design and consequently is not available in quantity commercially, but its ease and economy of production are noteworthy. During comparative tests it has been practically on a par with caterpillar types.

The performance of this vehicle has been the basis for further consideration of four-wheeled-drive tractors in competition with caterpillar types. The sequel to this test was the purchase of a Topp-Stewart F. W. D. tractor, which is now undergoing test at the Aberdeen Proving Ground.

Trucks with Adapters

The Ordnance Department has done a considerable amount of work in the adaptation to commercial vehicles of tracks for the betterment of their cross-country mobility. This work has consisted in general of applying tracks to Ford and Dodge cars and Militor trucks of both the 6 and 8-wheeled types.

It has been the aim in this development to so construct the track that it will be readily removable, thereby not interfering with the normal performance of such wheeled vehicles when traveling on roads. Space does not permit of a detailed description being given of these various types

of modified vehicles, but it may be stated in general that the development is promising and further work along this line will be undertaken.

One very interesting commercial development embodying this principle of conversion of commercial wheeled trucks to semi-track-layers for cross-country work is the 2½-ton Mack truck, with Roadless track adapter, shown in Figure 7.

A description of this mechanism showing the principles of construction is given in ARMY ORDNANCE, page 173, November-December, 1922, and page 228, January-February, 1923.

The chain or cable suspension and flexible track construction, the American patent rights for which are held by the Roadless Patents Holding Company of Washington, D. C., have been closely studied by the Ordnance Department for the past three years, and the application of the cable suspension principle has been applied to one experimental vehicle; namely, the Medium Tank No. 2, and there is now under construction at the Rock Island Arsenal the track embodying these principles for assembly to the Army Tractor, Model 1922. In addition to this, design is now under way of the Medium Tank, Model of 1924, which includes both the chain suspension and roadless track.

The first adaptation of this principle to a commercial vehicle in this country was in connection with the construction of an adapter for a 2½-ton Mack truck. This development was undertaken entirely with private funds, although the Ordnance Department has followed the design, manufacture and test quite closely, and at the present time the vehicle is at the Aberdeen Proving Ground where continuation of its test will be made under the direction of this Department. (See Fig. 7.)

An analysis of the construction will disclose the fact that there are but two experimental features in the design. All other details of construction are practically the same as are met in the construction of any track-laying vehicle. The two experimental items are the chain suspension and the track link construction. In reviewing the tests which have been made to date on this truck, it will be seen that practically no difficulties whatever have been encountered with the chain suspension, which leaves then the track links proper as the main item concerning which the additional tests will determine their value.

After completion of the truck it was run over the main highway from New York City to Washington, D. C., accompanied by an Ordnance observer. While in Washington the truck was demonstrated at Rock Creek Park and then sent to Camp Meade, Maryland, where preliminary runs were made prior to its official start on a 250 mile test run under the direction of the Commandant of the Tank School, with an Ordnance officer as observer. On completion of the test at Camp Meade, the truck was sent to the Aberdeen Proving Ground, where a further test of 250 miles was made.

In the test at Camp Meade the truck was run over a course which is about 5¼ miles in length, over variable terrain, one-third of which is across fields, over sand and gravel roads, which are soft, deeply rutted and with bad washouts after heavy rains, and over firm sandy turf. About one-third of the run up and down hills of sandy soil, having grades from 5 to 45 per cent. The conditions encountered are such as would be met by a vehicle traveling across country, and from the standpoint of track-laying vehicles, the course is not particularly severe, as any vehicle with tracks should negotiate the course without much difficulty, but it is doubtful if any wheel truck of either 2 or 4-wheel drive construction could cover the course under the worst weather conditions. The performance was entirely satisfactory.

The Mark VII Tractor Caisson

Without going into the details of construction it may be stated that in general the Mark VII tractor caisson is made up largely of standard parts of the 5-ton artillery tractor (Holt). The 5-ton tractor engine is used practically without change, but the transmission is altered to give sufficient gear reduction in order that it might stand up under the strains to which it was subjected.

Upon the completion of the pilot Mark VII vehicle, it was shipped to Washington, D. C., where demonstrations were given with the vehicle loaded to 4½-tons capacity. With this load the tractor caisson was able to climb grades

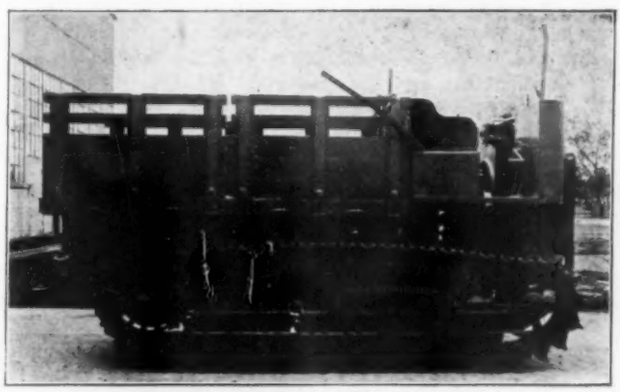


Fig. 8. Mark VII Tractor Caisson

of 44 per cent. After this demonstration the tractor was sent to the Aberdeen Proving Ground, where a test of 300 miles was made, including a road test to Washington, D. C., and return, traveling in all 190 miles over hard and rough concrete roads. (See Fig. 8.)

It was noted in the test at the Proving Ground that the vehicle could negotiate rough ground covered with ordinary obstacles, such as logs, etc. It was driven over rolling country in double high gear very satisfactorily, but when driven over soft marshy places, it would not pull in double high gear, necessitating a change to third speed. It was found to be impossible to turn the tractor caisson while in double high gear either on concrete surfaces or on soft ground.

It was possible during the test to attain a fairly high daily mileage of from 25 to 30 miles in approximately five hours running time, with but few stops during the run. Practically the only stop was for the adjustment of the track, which came entirely off its roller and sprockets, the replacement of which required two hours' work. In double high gear the tractor caisson attained a speed of 7½ miles an hour, and in third speed, 5½ miles an hour.

This tractor caisson has recently been sent to the Tank School, Camp Meade, for test to determine its value as a cargo carrying vehicle with Tank Units. Although no official report has been received in reference to this test, information has been given the Ordnance representative stationed there that the general performance of the vehicle is satisfactory, but that it is defective for use with tanks because of the absence of any angle of approach, front and rear, which makes it extremely difficult for the vehicle to cross wide ditches with steep banks.

If the design of a special tractor caisson with proper angles of approach to the track front and rear is undertaken, it is probable that a start will be made by modifying the Mark VII model to meet tank requirements.

Development of Commercial Tractors

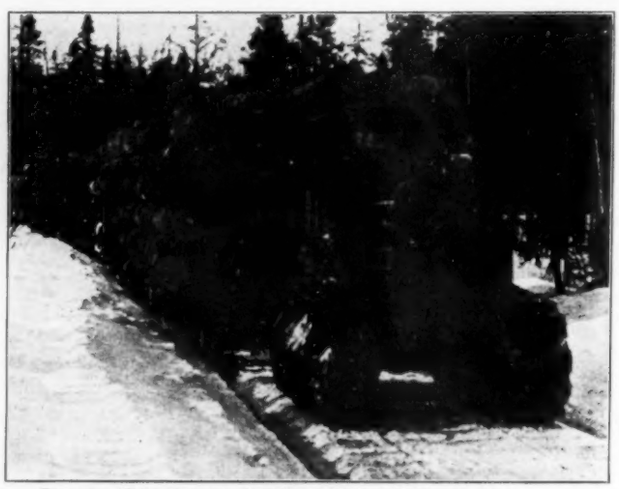
By

PLINY E. HOLT

THE successful use of tractors for military purposes during the World War has cleared the way for the thought that commercial tractors can be made to embody all the features necessary for military use without increasing cost or in any way reducing their serviceability or simplicity for commercial use.

It may be of interest to the followers of Ordnance development to know that the Holt Manufacturing Company is making a particular study of this combined problem and is endeavoring to produce tractors which will meet both sets of requirements as nearly as possible, as we find that we have many tractors working on construction, engineering and reclamation projects and logging that entail service fully as continuous and difficult as the most severe military requirements.

We are, in other words, striving to make our tractors, while primarily designed for industrial and agricultural work, at the same time suited to military needs, so that any emergency can be met with minimum loss of time and the least necessity for change in design.



Ten-ton Holt Tractor hauling 250-ton load of logs

Certain general characteristics of tractor design are more or less definitely established, such as the use of the four-cylinder gas engine power plant, the cylinders vertical and arranged longitudinally, radiator in front, and main clutch in the flywheel at the rear of the engine. Beyond these few very general characteristics, there are many variations in tractor design. As for our own product, the "Caterpillar" Tractor, we are standardizing in the newer models on certain features of design. At present we are using a front wheel only on our largest size machine. All other sizes are of the full-track type, with steering accomplished through separately controlled tracks so that the power can be applied to either through a steering clutch.

This manner of steering does not require operators of special training and experience. We have developed the pedal and handle arrangement along the lines of usual automobile and motor-truck practice. There is a master clutch pedal for the left foot, an individual brake pedal for each track, operated by the right foot, and a handle bar which controls the steering clutches in the natural manner of steering as, for instance, rotating the handle bar to the left releases the drive on that side, turning the tractor to the left.

The human element in tractor operation and success is a most important one. Commercially, it is important that the tractor should not only be powerful and enduring, but also that it should be easy to care for, easy to handle and comfortable to ride. The same factors are also of considerable importance in military work. I do not mean that we have arranged for the comfort of the operator to the extent of sacrificing other desirable elements of design, but we have given thought to the human considerations because a "rough-riding" tractor may be seriously detrimental to the health of the operator.

Both for military and industrial work, it is generally desirable to have two men on the driver's seat. Most of our tractors have seats sufficiently wide for that purpose. In orchard work for which our smaller models are largely used, a single seat for the driver located centrally as low as possible to avoid interference with low-hanging limbs of trees is desirable. These models can be equipped very easily with wide seats, convenient controls for military requirements. In all our models, seats are provided with backs and comfortable cushions. Enclosed cabs are available for cold weather and sun shades for desert heat.

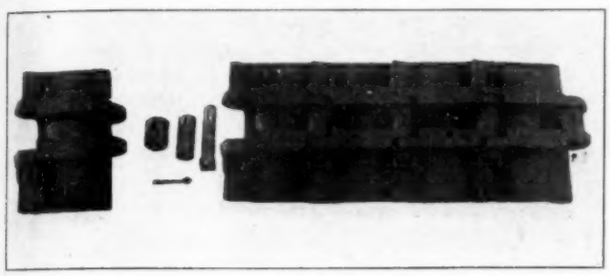
Some of the self-propelled "Caterpillar" Gun Mounts developed speeds as high as 30 miles per hour. Such high speeds are entirely uncalled for in commercial tractors, and it is questionable whether they are really necessary in military vehicles of this class. It appears that if a compromise must be made between the commercial tractor and the ideal military tractor, a considerable sacrifice will have to be made in the matter of speed. It is commercially desirable to have three speeds in a tractor. One speed being about three miles per hour, the speed at which a horse walks. A power speed of about one or one and a half miles per hour is usually provided, and a high speed of four to six miles per hour. For military purposes, a high speed of eight to twelve miles might be required, which would require no change in the tractor design except in the change-speed gearing. Where the tractor runs at high speed on hard roads, it should be provided with rubber tracks.

Rubber Track Development

The rubber track is a most interesting development, first started during the Panama Exposition in 1915 and greatly advanced by our gun-mount experience. We now build a rubber track by bolting short length of truck tire on each track line. These are made up from the

same steel-tire base and quality and thickness of rubber as used in the best makes of solid truck tires. The tire base is flanged only on edges, but this seems to be sufficient to hold the rubber, and is a cheap and well-tried design.

This rubber-faced track not only eliminates any shadow of criticism that the tractor may damage the road surface, but also absorbs road shocks so that tractors we have tested over long periods at continuous speed of ten miles per hour show not the slightest fatigue to any of



Track showing Renewable Roller to take wear of Sprocket

the parts. The use of rubber tracks give the tractor greater traction on hard roads and does not reduce the traction to nearly the extent that might be expected in the open fields, the rubber blocks having considerable grouser action on plowed ground. The rubber, contrary to our expectations and to what most people would assume, withstands the wear in a most satisfactory fashion, even the turning and scraping that results from the method of steering tractors of the track type. The only precaution that seems to be necessary is to keep the weight per square inch on the rubber shoes below fifteen pounds.

Our tests thus far indicate that the rubber track may prove ideal for almost every military purpose. It makes a real all-around tractor, for cross-country service and road or paved highway travel. For extreme conditions, spades or grousers can be put on over the rubber shoes, or a special type of steel track for ice and snow work can be put on in place of the entire rubber-faced track in ten to fifteen minutes.

Truck Design and Track Length

Much thought has been given to the design of the entire truck-and-track unit in its relation to the rest of the machine. It is necessary to balance the tractors carefully fore and aft. If the center of gravity is well forward, it will distribute the weight on the tracks evenly under load, because pulling a heavy load moves the center of gravity backward. A tractor thus balanced, however, will have a tendency to turn over frontward when it tries to hold back a load on a steep down-grade. A proper compromise of weight distribution must be determined.

It is necessary also to maintain good ground clearance and particularly to avoid any projections of the truck frames or other stationary parts, close to the ground, on which all or part of the weight of the tractor may be borne on rough ground or in crossing ditches.

It is as yet not quite settled how far the tracks should extend forward to make a design of general adaptability. As I just explained, the center of gravity is moved back when the tractor pulls a load, so in agricultural work it is not necessary that the tracks should extend very far forward. In industrial work such as road grading it is desirable that the tracks should extend as far forward as the front of the radiator. In military work a machine with too short a track when traveling over extremely rough ground would nose down, so it becomes essential that the tracks extend even slightly in front of the rest of the machine. It is difficult to say just what compromise can be reached between the military and commercial requirements. It is probable that tractors which meet industrial requirements will come near enough to meeting military requirements to prove satisfactory.

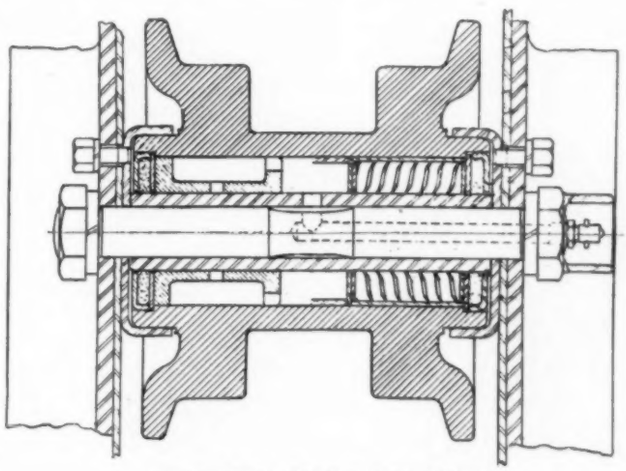
For much of the work for which tractors are sold, it is important that the over-all dimensions, especially width and height, be kept to the minimum. Limitation of dimensions is not of special advantage in military work but there is no disadvantage in it, so long as liberal ground clearance and low center of gravity are maintained.

Military Importance of Commercial Developments

It is interesting to note, as the reader may perhaps have already observed, that there are very few developments in tractor design of commercial importance that do not also have military bearing. For example, you might say that the army is particularly interested in obtaining a tractor to meet the emergency satisfactorily, but by making a tractor that will have longer endurance, we also make one that is less subject to breakdown in the field, and that, of course, is of extreme military consquence. We have given and are continuing to give a great deal of study and effort to the heat treatment of steels, in an effort to determine which are best suited to various purposes. The weak parts we are making stronger so that all will be brought up to a uniform high standard of life.

Lubrication

Another thing we are giving a great deal of study to is the matter of lubrication. Efficient lubrication is,



Truck Wheel Showing Dust Closure

of course, essential in all tractor work, but in most agricultural work the problem is complicated by reason of the fact that in many localities during a large part of the working season, the tractor operates in heavy clouds of dust. It does not take a great deal of this dust mixed with oil to change it from a lubricant into a grinding compound. Every precaution is now taken

to close the crankcase of the engine at every point with the best possible dust seal, and to arrange breathers so that dust cannot enter. This topic is important not only in connection with the engine, however, but also with all bearings, such as the truck wheels, front idler and final drive bearings. We use a heavy fluid oil for lubricating these parts and find it has this advantage over grease: It can be fed to the bearing in excess of actual requirements, the excess oil washes out the dust and leaves clean oil for lubricating. I cannot say that we have yet developed the most perfect means of dust closure for bearings such as those of the truck wheels, final drive, etc. We have made much progress, however.

Holt Tractor dredging Creek Bed

We find that we get very good results with a labyrinth type of closure. By using an excess of oil, a mud seal forms in the outer spaces of the labyrinth which prevents dry dust from entering. These labyrinths are sometimes supplemented by felt rings or packing as near the bearing surface as can be arranged, the felt keeping the oil from running out too rapidly. The oil feeds through the felt, keeping it well soaked, and finally works through the labyrinth slowly, as desired.

The success or failure of a tractor in the field is largely a matter of giving proper care and attention to lubrication. If lubrication and adjustments are properly attended to, repair and upkeep are greatly lessened.

Tractors which have been most successful in commercial use are those so desired as to provide every facility for proper lubrication and so cared for in service that this matter is given due attention.

Our company feels that the simplification of lubrication is of utmost importance. Our latest models require oil poured into three places—the engine, the transmission and the final drive housings—and forced by the convenient Alemite Gun to the ten other bearings. The only grease cups are two on the water pump. Such bearings as brake and clutch pedal fulcrums are made loose fits so that they do not require oiling. Ultimately, we hope it may be possible to put oil supplies into two places on the entire tractor—into the engine, and into a large transmission reservoir which will feed it to all chassis parts. Perhaps lubrication from this reservoir cannot be made automatic, but it appears that hand pumps can be provided which will take the oil and deliver it to all bearings not directly in the transmission housing.

From the military standpoint as well as commercial use, we know that the grade of oil available at some more or less isolated points may be an important factor in tractor success or failure. We have taken care of this by providing big bearing surfaces, pressure oiling and, as already explained, by keeping dirt away from all moving parts. There is undoubtedly a difference in the performance of different oils, but we try as far as possible to avoid the danger of any serious trouble arising from the use of cheaper oils—in other words, we aim to adapt our tractors for the use of oils of wide range of quality and viscosity.

We are also working along the lines of making it possible to use any ordinary fuel, and have found that by proper design of manifolds and combustion chamber, with correct valve size and timing, excellent results can be obtained with either gasoline, distillate or kerosene, without any change in the engine for a change of fuel.

This does not mean that all grades of fuel or oil are recommended or can be used with equal success, but that they can be employed where necessary.

The Importance of Air Clarifiers

Reference has been made to our efforts to keep dust away from moving parts. It is also essential to keep dust from gaining entrance through the carburetor That is another point to which very careful attention has been given. All the air that enters the carburetor is filtered through air clarifiers now that are nearly 100 per cent efficient in this respect, but they require some attention from the operator two or three times a week or even once a day under extreme conditions to clean the clarifier and wash out the dust which has accumulated in it.

Facilitating Repair Operations

I have referred to the efforts that have been made to increase the life and endurance of tractors. It is not, of course, possible to eliminate the need of repairs entirely, but we take this point into consideration in design, and one of our purposes is to keep unit parts down to a size and weight that make it possible for not more than two men to handle any part of the tractor. It is questionable just how desirable this is and whether, in the future, it will not become less and less necessary. For the present, however, even though we must sacrifice the economy of manufacturing a tractor with the fewest possible number of parts, we are avoiding excessively heavy units.

Another thing we are doing is to adopt the standards of the Society of Automotive Engineers for outside dimensions for nuts and bolt heads.

Tractor Versus Horse

In conclusion, a word or two may be appropriate on the general subject of the horse versus the tractor for military use. This is a subject on which so much might be said that it can hardly be discussed at sufficient length at this time. So far as favor of the horse is a matter of sentimnet—and a surprising amount of affection for the faithful four-footed animals exists—there is nothing to be said. On the basis of efficiency and economy, I think the tractor has all the best of it. The finest argument ever presented in favor of the horse is that he has a high degree of dependability, and the tractor has already reached such a state of perfection in this respect and such further advances are constantly being made that the future increased use of motorized tractive power is now a certainty.

Artillery Design

Part I

By

Brig. Gen. GOLDEN L'H. RUGGLES

THE subject which I will discuss in this and a subsequent paper is, "The Requirements of the Caliber Board and the Progress in Artillery Development Thereunder." Many of the members of the Army Ordnance Association are, no doubt, familiar with the report of the Caliber Board, so I shall not go into a discussion of the reasons which actuated that Board in laying down its requirements, but, in order to refresh your memories as to details, I will give a condensed statement of the requirements for Artillery for the different major tactical organizations, and I will discuss the advantages and disadvantages of the requirements, the difficulty or ease with which they can be met, the compromises in the requirements which have been agreed upon to date between the Ordnance Department and the combatant arms. I will then show briefly the development of artillery under the modified requirements up to date.

Brigadier General Ruggles

Divisional Artillery.

The requirements for Divisional Artillery are given on the next page.

No comment is called for in connection with the following items: Caliber of gun and howitzer; weight of projectile; rate of fire; simplicity of firing mechanism; and a single type of breech block. The other requirements I will discuss in detail as follows:

MAXIMUM RANGE—15,000 YARDS FOR GUN AND 12,000 YARDS FOR HOWITZER.

There is no difficulty from the Ordnance standpoint in making a gun or a howitzer to give these ranges within the limits of weight prescribed. A large part of the increase in range over that of the older types in use during the war has been obtained by improvements in the shape of the projectile and the remainder by increasing the muzzle velocity of the piece.

That part of the increase in range due to improvements in the shape of the projectile entails no complication of design or disadvantage of operation and so need not be further discussed for the present. The increase in muzzle velocity, however, necessitates an increase in the length of the gun which, in our experimental models is 131.7 inches over all, compared with an over-all length of the 3-inch, Model of 1902, of 87.8 inches, and of the 75 mm., Model of 1897, of 107.12 inches.

The increased length of the gun has entailed certain disadvantages of design and certain disadvantages in service. In order to avoid digging a hole in the ground when the longer gun is fired at high elevations, or in order to make this hole as small as possible, when it has to be dug, it is necessary to support the gun not at its center of gravity, as in the older designs, but at some point in the rear, as near the breech end as possible. Since the gun then revolves in elevation about a center not coincident with its center of gravity, it is necessary to compensate for the increased effort on the hand-wheel by providing an equilibrator system, which necessarily adds complications and weight to the design. Furthermore, the longer gun, when supported so far in the rear of its center of gravity, has considerable overhang in front of the trunnions and greatly increases the road stresses on the carriage, unless the gun be retracted to a traveling position, which of course, is inadvisable for divisional artillery. This increase in the road stresses, caused by the longer gun, will be taken care of in the design, but it necessitates additional weight. The longer gun necessitates increased road space on the march and causes interference between the muzzle and the ground when crossing ditches. This last difficulty cannot be avoided and must be put up with by the Field Artillery if it desires the increased range prescribed by the Caliber Board.

The securing of increased range by increase in velocity would ordinarily decrease very materially the accuracy life of the gun, but the Caliber Board has taken care of this by prescribing that only 10 per cent of the ammunition furnished shall be provided with the supercharge and that it shall be used only when necessary to outrange the normal charge. If this requirement be

strictly followed, the life of the longer gun should be increased for the wear on the new gun with the normal charge will be so much less than on the older models of guns firing the regular charges as to more than compensate for the increased wear incident to the 10 per cent of super-charges prescribed by the Board.

80 Degrees Elevation for the Gun.

Since the maximum range of divisional artillery can be obtained at an angle of elevation not exceeding 45 degrees, the only reason the Board had for prescribing an angle of elevation of 80 degrees is to permit the divisional gun to be used for defense against aircraft and this fact is stated by the Board itself. While it is not impracticable from an ordnance standpoint to design a gun having an elevation of 80 degrees, and while this was done in the first models of divisional artillery designed under the requirements of the Caliber Board, it entails many serious disadvantages. It complicates the design and makes more difficult the assemblage of the various parts into a compact and accessible whole. It increases the size of the equilibrator, adding weight to the carriage. It requires that variable recoil be used to prevent the breech of the gun hitting the ground unless a hole is dug, adding materially to the weight of the carriage and increasing the complication of the recuperator. The increased lever arm of the weight of the elevating parts at angles greater than 45 degrees, materially increases the frictional resistance between the moving parts when traversing at the higher angles, requiring the use of ball and roller bearings on the traversing pivot and adding weight and complications to the design.

These disadvantages have been so manifest that the Chief of Field Artillery, through his representative on the Ordnance Committee has indicated his desire that, for the present at least, no further attempt be made to provide an elevation of 80 degrees for the divisional gun, and the newer models now under test by the Field Artillery Board, which will be discussed later are designed for 45 degrees elevation only.

65 Degrees Elevation for Divisional Howitzer.

Similar considerations to those described above with respect to 80 degrees elevation for the divisional gun, have led the chief of Field Artillery to state through his representative on the Ordnance Committee that it is considered desirable by the Field Artillery that the elevation of the Divisional Howitzer be limited to 45 degrees.

360 Degrees Traverse.

While reasonably wide traverse such as may be obtained by the split trail carriage is desirable for the Divisional Gun and Howitzer, the principal reason for prescribing a traverse of 360 degrees is to enable the Divisonal Artillery to be used for defense against aircraft, and this is stated by the Board in its report. The Board speaks of a pedestal mount as being the ideal mount for a traverse of 360 degrees and it is evident that for this ideal a pedestal mount on a self-propelled caterpillar was considered.

From the first it was evident that the ideal type having a traverse of 360 degrees is so far in the future that no attempt has yet been made to design it. The feature of wide traverse is however incorporated in the split trail carriage. This feature necessarily introduces considerable extra complication, increases cost and increases weight, and so an alternate design—a box trail type with a limited traverse of 10 degrees—has been made in order that the Field Artillery may test out the two types and decide which one is the more suitable for their use.

Requirements of the Caliber Board for Light Field (Division) Artillery.

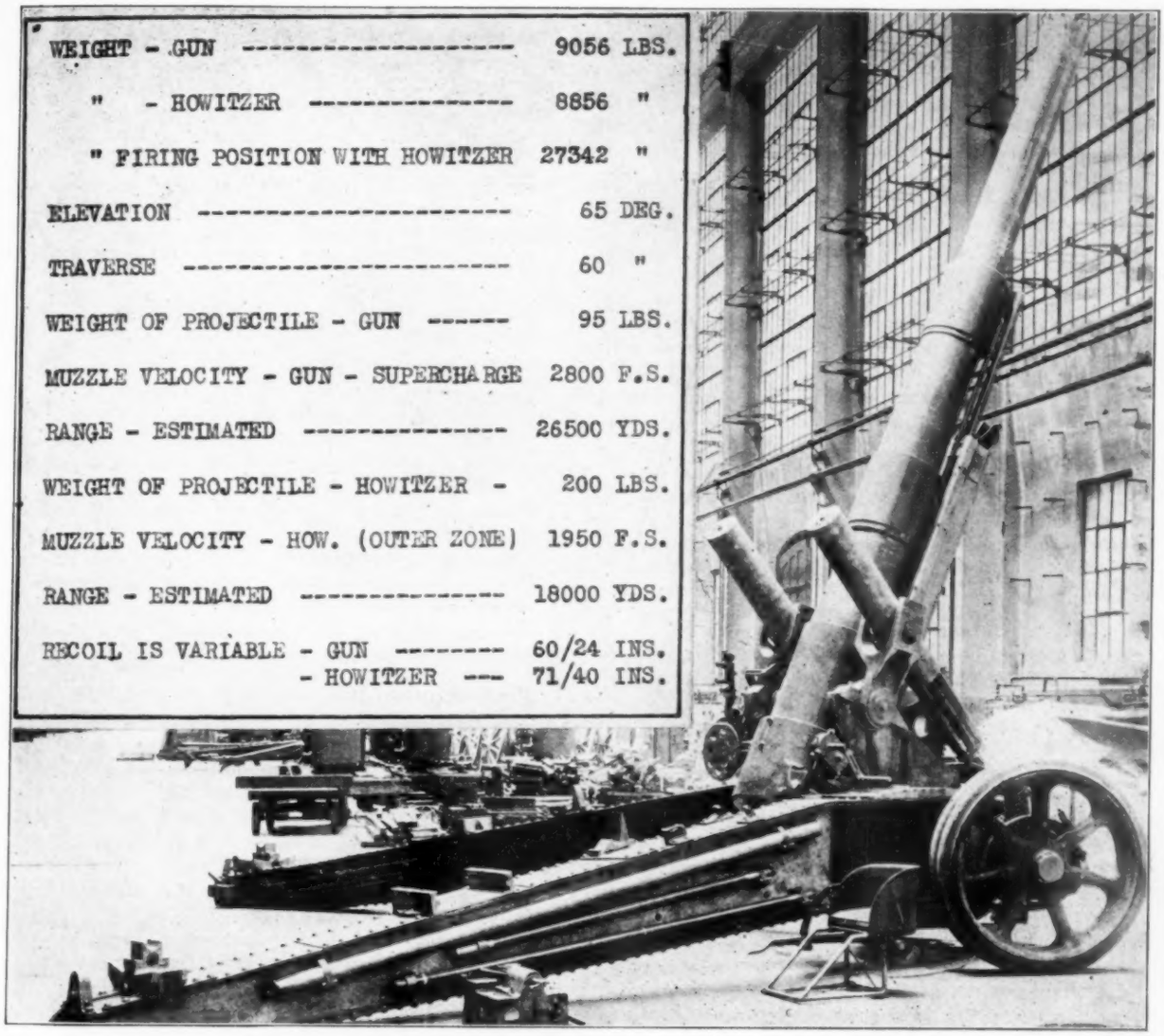
	Gun	Howitzer
Caliber	About 3 in.	105 mm.
Weight of projectile	Not over 20 lbs.	30 to 35 lbs.
Maximum range	15,000 yds.	12,000 yds.
Carriage to permit elevation of	80°	65°
Traverse	360°	360°
Weight	Not over 4,500 lbs.	Not over 4,500 lbs.
Range with normal or reduced charge	11,000 yds.	
Rate of fire, rounds per minute	20	

Carriage to be interchangeable for gun and howitzer.
Perfection of split-trail type recommended.
Wheels—to have rubber tires when motorized.
Development of self-propelled mounts.
Simple firing mechanism, preferably of lanyard type.
One type of breech block.
For normal use, a maximum speed of 12 miles per hour.

Carriage Interchangeability for Gun and Howitzer.

The idea of the same carriage for gun and howitzer when they are companion pieces appealed to the Board because of the expedition of production in quantity to be gained thereby and the simplicity of maintenance in the field. The first models of divisional artillery designed under the Caliber Board requirements adhere strictly to this feature even to the extent of using the same recuperator for gun and howitzer. There is however no tactical demand for a carriage interchangeable for the gun and howitzer and many disadvantages became apparent as soon as the design was undertaken. In the first place, the elevation specified for the howitzer was 65 degrees and for the gun 80 degrees. This required that the rockers for the howitzer carriage be provided for 15 degrees greater elevation than was needed for the howitzer, causing excess weight in those parts. The gun is also required to have an independent line-of-sight, while this is not specified for the howitzer and interchangeability of the carriage prevented the simplification of the howitzer carriage and the decrease

in weight permitted by the omission of this feature in the latter. The stresses brought upon the carriage by firing the howitzer are much greater than those brought upon it by firing the gun and so the interchangeable feature required that the gun carriage be mad econsiderably heavier than was otherwise necessary. In view of the necessity for all the mobility that can be obtained in the divisional gun, not only during transportation but while being manhandled in the firing position, anything that tends to uncarriage is worth the cost which must be paid for it in weight and complication of gun carriage. It is for the Field Artillery to decide whether the split-trail type is preferable to the simple box-tail type, so models of both types have been made for service comparison. As the model of split-trail type carriage first constructed embodied an elevation of 80 degrees and as during its construction certain improvements were noted which were later embodied in the design of the boxtrail type, it is


WEIGHT - GUN ---------- 9056 LBS.
" - HOWITZER ---------- 8856 "
" FIRING POSITION WITH HOWITZER 27342 "
ELEVATION ---------- 65 DEG.
TRAVERSE ---------- 60 "
WEIGHT OF PROJECTILE - GUN ------ 95 LBS.
MUZZLE VELOCITY - GUN - SUPERCHARGE 2800 F.S.
RANGE - ESTIMATED ---------- 26500 YDS.
WEIGHT OF PROJECTILE - HOWITZER - 200 LBS.
MUZZLE VELOCITY - HOW. (OUTER ZONE) 1950 F.S.
RANGE - ESTIMATED ---------- 18000 YDS.
RECOIL IS VARIABLE - GUN -------- 60/24 INS.
- HOWITZER --- 71/40 INS.

8-inch Howitzer Carriage, Model 1920E

necessarily increase its weight is, from a tactical point of view, very objectionable.

As a result of these considerations the Chief of Field Artillery has indicated through his representative on the Ordnance Committee, his desire that the feature of interchangeability of divisional gun and howitzer on the same carriage be omitted from future designs.

Perfection of Split-trail Type Recommended.

The subject of the split-trail type was touched upon above. The only reason for a carriage of this type is the greater angle of traverse that can be obtained with it. It is a question whether the wider traverse obtained by this considered necessary for a fair comparison of the two types that a new split-trail type be developed, providing an elevation of 45 degrees only and embodying all the improvements which have been put into the box-trail carriage.

Wheels to Have Rubber Tires When Motorized.

The addition of rubber-tired wheels to motorized artillery is apparently necessary to decrease road stresses on the vehicles when hauled rapidly by truck or tractor for long distances, particularly over hard roads. A disadvantage resulting from the application of rubber tires on wheels is the increase in the total weight of the carriage and limber by 340 pounds.

Development of Self-propelled Mount.

The Caliber Board lays great stress on the development of self-propelled mounts.

For divisional artillery, the principal requirements of the mounts are a maximum speed of 12 miles per hour and a weight limit imposed by the pontoon bridge. Since the pontoon bridge for the cavalry division has a capacity of only 9,000 pounds, this will be taken as the weight limit for the divisional mount. It is believed that these requirements are entirely practicable from an engineering standpoint.

Three models of a self-propelled mount for divisional artillery have been made up to the present time—the Mark VII, which was designed and nearly completed before the Caliber Board made its report, the Christie mount, which was designed after the Caliber Board made its report; and the Mark VI, designed by the Holt Manufacturing Company after the Caliber Board made its report. All three of these mounts are now undergoing service test by the Field Artillery.

The Mark VII mount has been under test at Fort Sill since February, 1920, and a report upon the test has been made by the Field Artillery Board. This report states that the mount has sufficient speed, stability and mobility, but that certain defects noted by the Board should be corrected and the total weight of the gun and mount should be reduced to not over 10,000 pounds.

The Board commented at length on the principle of the self-propelled mount and stated that, in its opinion, its characteristics are not such as to make its use for divisional artillery desirable, but that it has a possible field of usefulness as an infantry accompanying gun.

A minority report stated that there are four possible uses for the 75 mm. self-propelled mount—

(*a*) As an infantry accompanying gun;
(*b*) As reenforcing artillery, such as the French porté;
(*c*) As an anti-tank gun;
(*d*) To accompany a field of tanks.

Both the main report and the minority report recommended that the development of the self-propelled mount be carried on energetically.

The Mark VII and Mark VI self-propelled mounts have tracks of the conventional type. The mount of the Christie type embodies the principle of running on good roads on rubber-tired wheels and across country on a caterpillar track. For running on ordinary roads, the construction is about the same as the ordinary truck. For running across country, a track is placed over the rubber-tired wheels and is driven by teeth on the track engaging with metal recesses in the driving wheels between the two rubber tires. The Christie type of mount is attractive for the reason that, if the type were satisfactory, it could run on good roads on rubber tires at considerable speed without heavy wear on the mechanism, and could run across country on caterpillar tracks. Mechanical difficulties have developed, however, in this type which are largely inherent in the design and further experimentation and considerable redesign will have to be done before it can be finally determined whether this type can be made entirely serviceable.

None of these mounts is satisfactory, and the design of a fourth mount by the Ordnance Department has been undertaken, although it has not progressed far up to the present time.

In all of the three mounts cited above the mistake was made of attempting to give them too much speed—much more than was required by the Caliber Board. If the speed of the mount be limited to 12 miles per hour, it is believed that a satisfactory mount can be designed and that the total weight of gun and mount will not exceed 9,000 pounds.

One of the main difficulties so far encountered in the tests of these self-propelled mounts is that the track does not show sufficient endurance at the high speeds required. By limiting the speed to 12 miles per hour and by modifications of the track mechanism now in contemplation, there is great possibility, even probability, that a track may be developed that will be serviceable for at least 1,000 miles. Whether such a track can be operated for 1,000 miles at a speed of 12 miles per hour on hard roads, is a question that cannot be definitely answered at the present time, although new designs of track mechanism are promising even in this respect. If such track mechanism can be developed, it would obviate the necessity of embodying the Christie principle and the complications that necessarily go with it. Meanwhile the Ordnance Department has still in mind the further development of the Christie principle and of the straight caterpillar track.

Pack Artillery

The Caliber Board requirements for ideal pack artillery are—

Caliber, about 3 inches.
To use projectiles of division gun, if possible.
Range not less than 5,000 yards.
Elevation, at least 45 degrees.
Weight of pack loads, about 225 pounds, exclusive of pack equipment.
Panoramic sight.
No shield.
Ammunition, semi-fixed.
Powder, smokeless-flashless.
About four zones.
Capable of being pulled on wheels by crew on normal ground and for short distances over any ground.

It may be stated that none of the requirements set forth is at all impracticable from an engineering standpoint at the present time. The only difficulty is to so design the matériel that it can break up into the necessary loads of the proper weight and of such shape and balance that they can be packed satisfactorily on a mule and can also be assembled together to afford a sufficiently rigid structure for a gun and mount. The requirements for ammunition are not essentially different from those of the divisional gun and will be discussed later.

One model of pack artillery has been designed and manufactured in strict conformity with these requirements, except that the range of the piece was increased to 6,500 yards. This model has been tested at the proving ground and at Camp Stanley. Certain defects have been found in this model, the principal of which are as follows—

(*a*) Lack of stability for low-angle fire;
(*b*) Defects in the mechanical construction of the joints between the parts which have to be separated to limit the weight of pack loads to 225 pounds;
(*c*) Also certain defects in the sights which are readily corrected.

A new design of pack artillery was therefore undertaken to correct the defects noted in the first design. The drawings for this have been completed and a wooden model has been made, but before manufacture of the new design could be undertaken, it was learned that foreign countries are preparing to equip their armies with pack artillery

having a range as great as 9,500 yards. Studies have therefore been made of a pack howitzer to fulfill all the requirements of the Caliber Board, except that the range has been increased to 9,000 yards, and a wooden model of this material has been constructed which is very promising. The weight of the individual pack loads will be kept to about 225 pounds, exclusive of pack equipment, but it is necessary to divide the material into six loads instead of four.

Corps Artillery.

The Caliber Board requirements for Corps Artillery are:

Medium Field (Corps) Artillery.

	Gun	Howitzer
Caliber	Between 4.7 in. and 5 in.	About 155 mm.
Weight of projectile	Not over 60 lbs.	Not over 100 lbs.
Maximum range	18,000 yds. supercharge	16,000 yds.
Range, normal charge	12,000 yds.	Zones
Elevation	— 5 to + 80°	— 5 to + 65°
Traverse	360°	360°
Maximum rate of fire	6 rounds per min.	5 rounds per min.

Generalities—

A split-trail carriage should be developed for Howitzer interchangeable, if practicable, with that for gun.

Maximum speed of 8 miles per hour.

Wheels for carriage should be rubber-tired.

Transport fully motorized, with wheel trailers for long rapid hauls.

Weight limit, 12,000 pounds for wheeled vehicles; and 15,000 pounds for caterpillars.

These requirements are not difficult of accomplishment from an engineering standpoint, except with respect to 80 degrees elevation for the gun, 65 degrees elevation for the howitzer, 360 degrees traverse for both, the interchangeability of the gun and howitzer on the gun carriage, and the weight limits prescribed.

The objections to an 80 degrees elevation for the corps gun and a 65 degree elevation for the howitzer are of the same nature as those discussed in the case of the divisional artillery.

Owing to its impracticability, no attempt has been made to provide 360 degrees traverse in the wheeled mount, particularly as the split-trail type of carriage permits 60 degrees traverse for both gun and howitzer.

The objection to using the same carriage for both gun and howitzer is more marked in the case of the corps artillery than in the case of the divisional artillery, because of the greater divergence in the strains brought upon the mount by the corps gun and corps howitzer. The large increase of range required over that given with the same angle of elevation by the 4.7-inch gun, Model of 1906, has been obtained by improving the form of the projectile and by increasing the muzzle velocity and therefore the length of the gun.

There is no difficulty in obtaining a maximum speed of eight miles per hour when the carriage is trailed behind trucks or when the gun is mounted on a self-propelled mount.

At the present time it is impracticable to design a self-propelled mount for either the gun or howitzer to come within the weight limit of 15,000 pounds. In this connection it should be stated that, since the capacity of the medium pontoon bridge is now 30,000 pounds, it does not seem necessary to restrict the weights of the wheeled carriage in accordance with the Caliber Board requirements at the expense of requiring the gun to be withdrawn to a transport wagon for transportation.

With respect to wheeled trailers, no attempt has yet been made to prepare a design of this kind for the reason that the necessity for it has not been apparent to the Ordnance Department or to the using service.

A gun and howitzer have been manufactured in accordance with the requirements set forth above, except that the gun is limited to an elevation of 65 degrees. Two split-trail carriages have also been built on which either the gun or the howitzer can be mounted. These carriages fulfill the requirements specified above, except that each, limbered, weighs about 15,830 pounds, or 13,475 pounds in battery.

During the progress of the design it became apparent that, since the carriage had to be made strong enough for the howitzer, a gun of much greater power than prescribed by the Board could be mounted thereon. For this reason the gun was designed for a muzzle velocity of 2,560 feet per second, with a 50-pound projectile, and a range of 22,000 yards. Later, in order to decrease the size of the hole that had to be dug for the gun to recoil into at high elevations, it was decided to reduce the length of short recoil for the gun from 36 inches allowed the howitzer to 21 inches. This reduction in the length of recoil required that, in order to avoid overstraining the carriage, the muzzle velocity of the gun be limited to 2,450 feet per second, and the range to 20,500 yards. This material has been received at the proving ground but recent and preliminary firings indicate that the top carriage will have to be strengthened.

The disadvantages of providing a carriage for corps artillery on which either the gun or the howitzer can be mounted, and of elevations greater than 45 degrees for the gun, became so apparent during the design and construction of the material, that it was decided, with the full concurrence of the Field Artillery, to omit these features in future designs.

A new design for a gun and carriage has been made and the material is now under construction. By building the gun for a muzzle velocity of 2,450 feet per second and a range of 20,500 yards, by omitting the variable recoil pro-

vided for the first matériel, by providing for 45 degrees elevation only instead of 65 degrees, and omitting the quick-release mechanism required for loading at angles of elevation higher than 45 degrees, the gun and carriage limbered can be brought within the weight limits prescribed of 12,000 pounds.

60 degrees and a total traverse of 30 degrees. Its weight will not exceed 22,000 pounds. While nearly 50 per cent heavier than the figure prescribed by the Caliber Board, it is well within the weight limits of the medium pontoon bridge. It is believed that this is a very promising development for corps artillery.

Heavy Field (Army) Artillery.

	Gun	*Howitzer*
Caliber	About 155 mm.	About 8 inches
Weight of projectile	Not over 100 lbs.	Not over 240 lbs.
Maximum range	25,000 yds.	18,000 yds.
Range, Normal charge	18,000 yds.	Zones
Elevation	Zero to 65°	Zero to 65°
Traverse	360°	360°
Type of projectiles	H. E. shell	H. E. shell

Self-propelled caterpillar unit desirable for 155-mm. gun.

Certain proportion should be retained on rubber-tired wheel mounts.

It is desirable to develop a carriage which can be used interchangeably for 155-mm. gun and 8-inch howitzer.

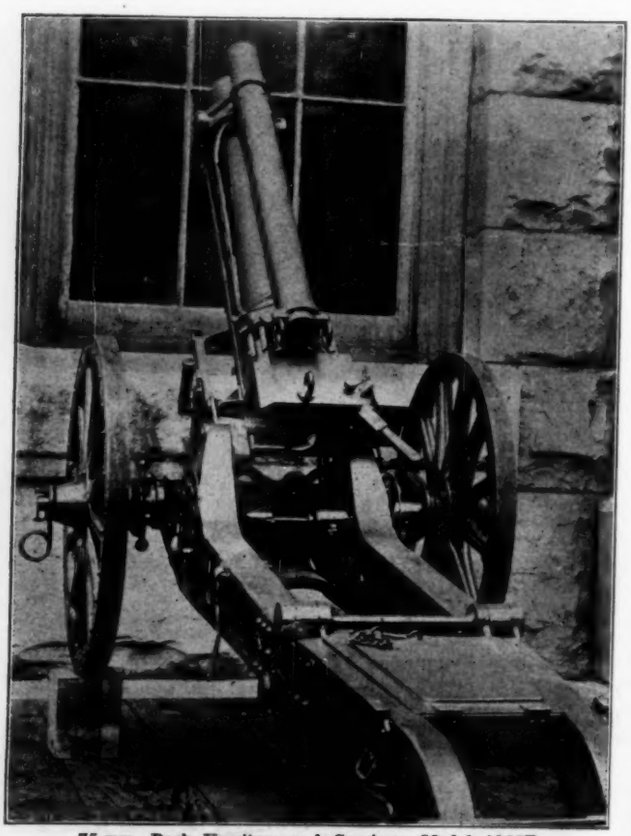
Maximum speed of S. P. caterpillar, 6 m.p.h.; wheel mounts, 12 m.p.h.

Conventional caissons for this caliber are obsolete.

Transport: All of this type should be motorized.

Ammunition vehicles to correspond should be developed.

A self-propelled mount is under manufacture for the gun first built. This mount, which is also capable of



75-mm. Pack Howitzer and Carriage, Model 1922E

handling the howitzer, will have a maximum speed of 20 miles per hour on good roads, will permit an elevation of

Army Artillery

Requirements for heavy field (Army) Artillery are given above.

The remarks made while discussing the requirements for the smaller calibers apply also to the elevation of 65 degrees and the traverse of 360 degrees called for in this case, though an elevation of 65 degrees is not so great a disadvantage in the case of the army weapons, as they probably would require variable recoil and a quick release mechanism in any event. It happens that the firing stresses developed by the 155 mm. gun and 8-inch howitzer prescribed are sufficiently alike that no difficulty presents itself in providing a carriage upon which the gun and howitzer can be mounted interchangeably. Subject to these remarks no difficulties are presented in designing the matériel in accordance with the requirements, except as to weight.

The Caliber Board omitted any requirements as to weight for this matériel but it is evident that it should be kept, if possible, within a limit of 30,000 pounds, the capacity of the medium pontoon bridge.

As priority in development under the Caliber Board requirements has been given to the smaller calibers, progress on this matériel has not been so great as on the former. There have, however, been completed and shipped to the proving ground one split-trail carriage capable of mounting either the gun or the howitzer, and two self-propelled mounts capable of mounting either the gun or the howitzer. Two guns have been made, one of chrome steel and the other wire wound, and two howitzers, one of chrome steel and the other wire wound. The test of this matériel has just been inaugurated and it is not possible therefore to say much about its performance under test, although there is nothing to indicate that it is not sufficiently strong.

Figure shows the 155-mm. gun—8-inch howitzer carriage, Model 1920. This carriage is similar in many respects to the G. P. F. gun carriage and to the 4.7-inch

gun and 155 mm. howitzer carriage, Model 1920. It has a quick release mechanism similar to that described for the latter carriage. The carriage is spring mounted while traveling and for firing the load may be taken off the springs and transferred directly to the axle by means similar to those provided for the 4.7-inch gun and 155 mm. howitzer carriage.

The panoramic sight and quadrant sight are mounted on the left rocker.

A transport wagon is provided for the piece, though it may be retracted and transported on its gun carriage if desired. The transport wagon and method of transfer of the piece are similar to those provided for the 4.7-inch gun and 155 mm. howitzer carriage.

Weapons of Greater Power

The Caliber Board requirements for the gun and howitzer listed by the Board under "Weapons of Greater Power" are:

Heavy Howitzer of Greater Power

Caliber, about 9½ inches.

Elevation, 0° to 65°.

Traverse, 360°.

Carriage to require little preparation for fire.

Maximum speed need not exceed 6 miles per hour.

Maximum load should not exceed 20 tons—certain percentage should be on wheel mount so maximum load on four wheels will not exceed 12 tons.

Weight for projectile, not over 400 pounds.

Maximum range, 25,000 yards.

Separate loading and related zone smokeless-flashless propelling charges.

Three kinds of H. E. shell permissible.

Transport, caterpillar drawn or caterpillar mount.

Heavy Gun of Greater Power.

For missions requiring the use of direct fire and of a projectile weighing more than the 155-mm. gun, and greater range.

A limited quantity to be provided.

Maximum range, 35,000 yards.

Weight of projectile, about 220 pounds.

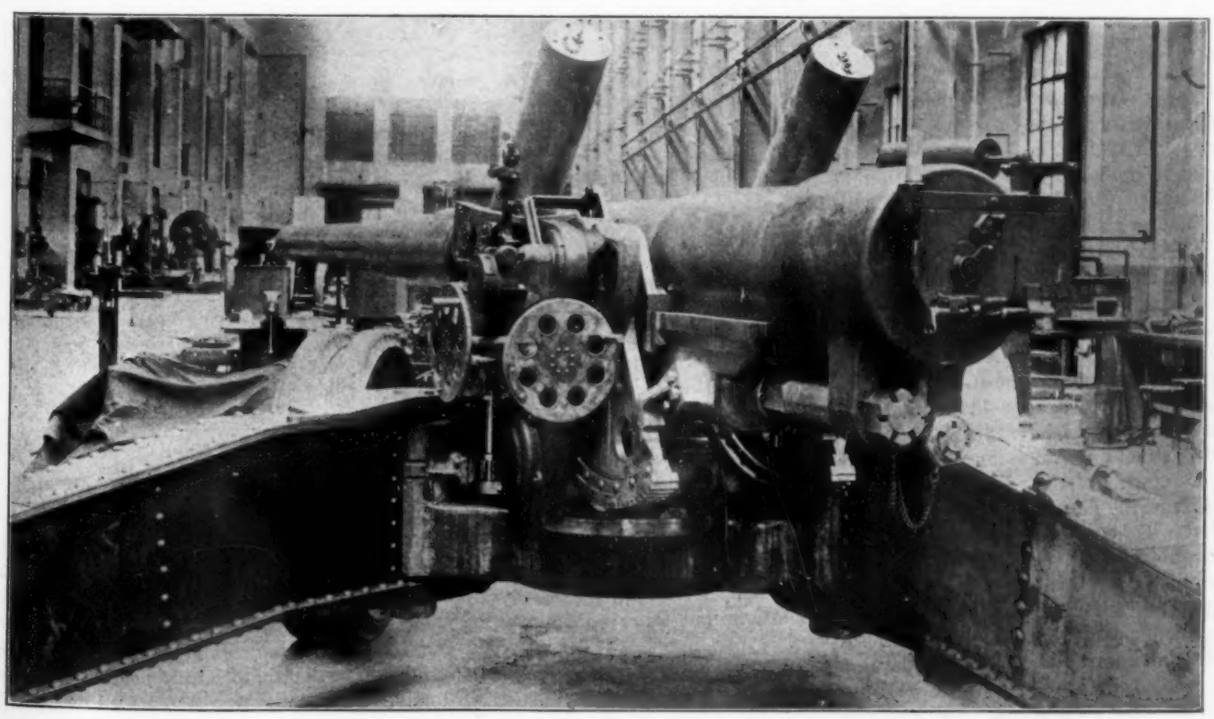
The board had in mind the development of caterpillar type of carriage.

Maxmum elevation not stated, but presumably only that necessary for maximum range.

A design for either the gun or howitzer alone of the power indicated presents no difficulty and, while no weight limit was fixed by the Board for the carriage for the gun, it is evident, since these are companion pieces, that it should not differ greatly in weight from that for the howitzer. The howitzer carriage was limited to a maximum weight of 20 tons. The Board indicated in both cases that it has in mind a self-propelled mount, although under the howitzer requirements it is stated that a certain percentage should be on wheel mounts, and that the maximum load on the four wheels should not exceed 12 tons.

The amount of development work laid out by the Caliber Board is manifestly much greater than can be handled at one time by the Ordnance Department with the funds and personnel available and therefore it was necessary to assign priority to the various projects outlined by the Board. Weapons of greater power are listed low in the order of priority and so a great amount of progress has not been made upon them.

However, studies of the gun and the howitzer and of a caterpillar carriage that will mount the howitzer have been made. To obtain a range of 35,000 yards with the gun and projectile specified requires that the gun weigh about 40,000 pounds and have a muzzle velocity of 3,200 f. s., with a 200-pound shell, and, to obtain a range of 25,000 yards



155-mm. Gun Carriage, Model 1920E

with the howitzer requires that it weigh 25,000 pounds and have a muzzle velocity of 2,350 f. s.

It is manifestly impossible to design a self-propelled mount for these weapons that will come within the weight limit prescribed of 20 tons, and so an effort has been made to keep the weight within the limits imposed by the capacity of the adopted engineer type of fixed highway bridge, which is a maximum single load of 80,000 pounds.

The Board states that this type of equipment overlaps in its use the field of the 8-inch gun referred to hereafter as a railway type of mount. With a maximum weight of 80,000 pounds it is evident that the matériel will be limited to maneuvering in a district where there are no large streams to cross or where first-class highway or railway bridges exist, or where it may be placed upon barges and ferried across streams. Railway artillery is limited to the rails and this matériel which can be placed easily upon a flat car and transported by rail has this advantage over railway artillery, that, having been transported by rail as far toward the front as railway guns can be taken, it can proceed off the car under its own power and travel to any point within the area away from the railroad track, where it may be needed and which it may reach without having to cross streams for which no adequate bridges or ferries are available.

In the type of mount tentatively adopted there are two units; one the howitzer mount proper and the other a unit which provides power for the operation of the electric motors that drive the tracks of the mount. This unit, or prime mover, is intended also to carry ten tons of ammunition.

On the mount there are two pairs of caterpillar tracks, each track driven independently by an electric motor. The power is furnished by the prime mover through a flexible cable which may be reeled in or out to suit the circumstances of travel by a man on the prime mover. When desired, the prime mover may also be coupled to the mount by the ordinary drawbar to directly assist the electric motors in driving the mount.

The girders connecting the front and rear caterpillar tracks of the mount remain always parallel to the axis of the rear track. The howitzer provided with the ordinary recuperator and elevating mechanism is mounted in trunnion beds on the girders. It is expected, when the carriage is designed, to provide gearing for giving a limited amount of traverse to the gun by sliding the front of the girders on their seat in the front caterpillar track. The girders are attached to the front track by a universal joint, which permits the tracks to conform to the ground over which the mount passes and also enables the front caterpillar track to be turned at right angles to the axis of the piece. When so turned the front track can be used to turn the whole mount through 360 degrees around the rear track as a pivot.

The prime mover is equipped with a gasoline engine and electric generator set and individual electric motors on each track.

One great advantage of having a separate prime mover for the mount with separate electric motor drive for each of the six tracks is that it keeps the requirement for maximum power to a miminum because, if required, either the prime mover or the mount can stand still and all the available power be utilized for moving the other to the limits of the length of the cable. In this way the two units can proceed on very difficult grades with the power requirement for the greatest single load only.

(*To be continued.*)

Automotive Engineers Discuss Army Needs

The War Department is endeavoring to have cross-country cargo-carrying vehicles of a single type developed that will be suitable for use by all branches of the Army in war times. The type of vehicle desired is that to be used beyond the zone of operation of Army trucks. The Ordnance Committee is formulating the general specifications for such a vehicle.

On June 20, representatives of the Army Ordnance Department conferred with the Ordnance Advisory Committee of the Society of Automotive Engineers at Spring Lake, N. J. As was expected, besides the Advisory Committee there were other representative engineers of the Society present to advise the Committee in formulating specifications and to discuss the availability of commercial products that might be utilized in emergency. The Ordnance Department is very much interested in cooperating with the manufacturers of automotive material in order to encourage the development of cross-country types of vehicles that will be suitable for use in the Army. This particular cargo-carrying vehicle that is intended for general use is probably not available commercially at present, but it is hoped to stimulate interest with the expectation that there are sufficient fields of usefulness for such types in commercial life to warrant their development for production.

The Ordnance Advisory Committee of the S. A. E. includes such men of national prominence as:

Mr. B. B. Bachman, Chief Engineer, Autocar Company; Mr. H. W. Alden, Chairman of Board of Directors, Timkin-Detroit Axle Company; Mr. Chas. M. Manly, Consulting Engineer, New York City; Mr. W. G. Wall, Vice-President, National Motor Car & Vehicle Corporation, Indianapolis; Mr. George W. Dunham, Consulting Engineer, Savage Arms Corporation, Utica, New York.

Other men well known in the industry who were present were:

Mr. Alfred F. Masury, Chief Engineer, International Motor Company; Mr. J. R. Coleman, Factory Manager and Chief Engineer, Southern Truck Corporation, Rochester; Mr. Chas. L. Sheppy, Chief Engineer, Pierce-Arrow Motor Car Company, Buffalo.

Representatives of the War Department who attended the conference were:

General C. L'H. Ruggles, Ordnance; General S. D. Rochenbach, Tank Corps; Colonel George Vidmer, Cavalry; Lieutenant-Colonel Edgar S. Stayer, Quartermaster; Major C. F. Jenks, Ordnance; Major W. P. Boatwright, Coast Artillery; Major W. R. Scott, Infantry; Major J. W. Anderson, Field Artillery; Major B. O. Lewis, Ordnance; Major A. B. Quinton, Jr., Ordnance; Major G. P. Wilhelm, Ordnance; Captain G. W. Outland, Ordnance; Mr. George Schuster, Ordnance Engineer; Mr. A. B. Whittet, Ordnance Engineer.

Trailmobile Universal Chassis

By

CALEB W. SHIPLEY

DURING the period between the Civil War and the World War military science discovered substitutes for or improvements on pretty much everything with the exception of the enlisted man and his humble servant, the Army mule. The former, equipped with modern agencies for destruction and defense, and with his area of effective operation multiplied on land and extended into the air, still bears the brunt of action, and he always will. But despite all the developments and improvements in the science of transportation, he still is dependent upon the much-cussed, but indispensable, quadruped that boasts neither pride of ancentry nor hope of posterity. For wherever the nature of the terrain puts a halt to motor truck and tractor, there the unloved and unlovely mule hauls ammunition and provisions, water and gasoline, field kitchens and field hospitals, ambulance and ordnance, aircraft equipment and engineering supplies. There is every reason to believe that the Army mule will remain essential to military effectiveness so long as there are wars to fight.

Belt Tire for rear wheels, showing method of attachment

But marvelous as have been improvements in the science of military transport, due to the automotive industry, revolutionary as have been the effects of the motor truck and the tractor, multiplying the effectiveness of every combat unit by increasing its flexibility, the exigences of the World War very quickly demonstrated the inadequacy of animal-drawn equipment in every branch of the service, of which the standard escort wagon may be regarded as fairly typical. This type of conveyance has undergone little change in design from the escort wagons of Civil War days, as immortalized in the heroic relief work on the facade of the Pension Building at the National Capital. In fact, the light transport wagons of 1914 were essentially the same as those used by General Washington in Revolutionary days, with little evidence of having been influenced by the history-making developments in the automotive arts. Like Tennyson's "Brook," the escort wagon may well be credited with saying:

"Men may come and men may go,
But I go on forever."

General Funston realized this condition when called on to command the raiding operations into Mexico, on the trail of the international bandits. His reasoning was characteristically direct and logical. "An automobile or motor truck will pull more than it can carry. Troop movements cannot accomplish their purpose if speeded down to the gait of mules. Let us utilize our power units at something like their full capacity by making them do the work of draft as well as of dead-load hauling. Try the trailer." Such was the substance of the General's reasoning and the sum of his conclusions. The result was that one truck hauled not only its own regulation load and an auxiliary Trailmobile with a ton of supplies, but four Trailmobiles with four tons of supplies, plying regularly between General Pershing's headquarters in Mexico and the base of supplies at Columbus. This was a grilling test, both of the principle of trailer transportation and of applicability of the Trailmobile to the requirements of any army in actual field operations and its adaptability to the regulation army trucks. Yet the first suggestion to introduce trailers into the service on the border had been met with the statement that there were no trailers built that could stand up under the service required and no trucks that could pull trailer equipment over the almost trackless sands of Mexico. It took the practical field needs of an expeditionary force in actual military operation to prove the efficiency of the trailer, as applied to truck draft and to demonstrate that the Trailmobile will follow wherever the motive power unit can find traction. Today, as evidence of the practical acceptance of trailers by the War Department, you will find the pintle hook for trailer draft on the rear of the trucks of the Department.

When the United States entered the World War the escort wagon was the accepted unit of transportation and its one and one-half ton capacity was the standard load. The Government was prompt to avail itself of the fruits of the experimental tests on the Mexican border, and called on the Trailmobile Company to furnish for overseas field service fleets of trailers similar in basic engi-

neering design to those that had rendered such satisfactory results in Mexico, but with a load capacity of one and one-half tons, and built for interchangeable service both as trailers with truck or tractor draft, and as escort wagons drawn by animals. So satisfactory were the services rendered by these that Trailmobiles soon were doing work in practically every branch of the service, vastly increasing the net efficiency of trucks and tractors in transporting men and supplies over roads and main arteries of military movement, and when not in this use, doing the innumerable jobs of troop and equipment transportation where there were no roads and where only mules could go. It would be tedious to enumerate all the uses to which the Trailmobile was put during the period of our country's active participation in the war and the occupation of the Rhine territory after the signing of the Armistice. Such an enumeration would read like a mere cataloging of transportation activities. Those readers of ARMY ORDNANCE who participated in the expeditionary operations had ample opportunity for personal observation of Trailmobile service, between eight thousand and ten thousand standard Trailmobile one and one-half ton units, with interchangeable chassis and equipped with draw bar for truck draft and pole for animal draft, having been delivered and placed in service. At the close of the war production of these units was on a basis of one hundred and twenty-five per day, the quota indicated by the Government as representing its estimated requirements for war service.

Trailmobile at McBride's Ford, Fort Benning

Some twelve months after the close of the war the manufacturers of the Trailmobile were requested by officers of the War Department to visit Washington for the purpose of entering into a conference with reference to such modifications in design as should preserve all the elements of effectiveness that had rendered the Trailmobile so useful in overseas service, while increasing its flexibility. In this connection it should be remembered that the Trailmobile, as its name implies, was originally designed as a trailer, pure and simple, to be used as an auxiliary to motor truck or tractor. At the outset its inventors were actuated primarily by considerations of ordinary commercial utility with little immediate reference to the complex and specialized requirements of military use. The Trailmobiles that General Pershing's "Little Expeditionary Force" used in Mexico were of this type, with no special modifications to make them peculiarly adapted to army purposes. The Trailmobiles that did service with Pershing in the "Great Expeditionary Force" in Europe, were little different from those used in Mexico, save for their larger load capacity, which, of course, necessitated some increase in weight and structural strength. The performance of the Trailmobile, a civilian drafted into military service, was therefore the more significant, as it gave grahpic and convincing proof of the superiority of the automobile type of wagon design over the old "standard escort" type, even in the field in which the latter had held undisputed sway practically ever since the days of Julius Cæsar.

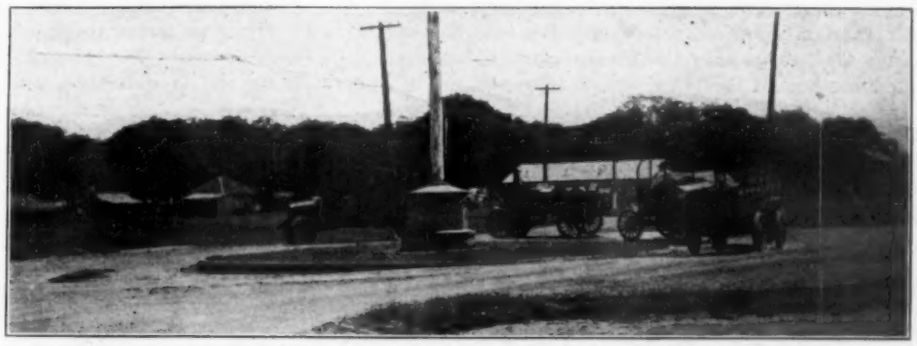
Trailmobile with Belt Tires after crossing a small stream by means of Chain and Tractor

What, then were the essential features of the theoretically ideal military light transport wagon, and how nearly could they be incorporated in the Trailmobile?

These were the questions for which the officers of the War Department were seeking answer. To formulate the specifications of their requirements was the province of the War Department officials. To incorporate these in the completed unit was the manufacturer's problem. To apply the rigorous service tests of actual field use was again the province of the Army. It is the purpose of this article to give readers of ARMY ORDNANCE a summary of results.

Requirements

STANDARDIZED, UNIVERSAL, INTER-CHANGEABLE CHASSIS EQUALLY ADAPTABLE TO TRUCK OR TRACTOR DRAFT AND ANIMAL DRAFT.—The importance of standardization is too obvious and has been demonstrated in military practice, as well as in commercial fields, too thoroughly to call for extended comment in this connection. The standard universal chassis means maximum efficiency not only at lowest production cost, but also at minimum operative outlay—fewest parts, extreme mechanical simplicity, reducing the "dead time" required for repairs and enabling the unskilled enlisted man to make replacements and adjustments without calling on the departments of expert technical service.



Trailmobiles being drawn behind 1-ton truck around Flagpole Circle, Fort Benning, Ga.

Comparison of ruts made in cornfield by Standard Escort Wagon and Trailmobile with Belt Tires

THE UNIT MUST BE ABLE TO NEGOTIATE ANY TERRAIN WHERE TRACTIVE POWER IS AVAILABLE.—Military transport cannot wait for good roads, but must be able to go wherever the fighting man goes. Moreover, in actual troop movements of a major character, even where hard roads exist, the main arteries of transport must, of necessity, be given over primarily to the heavy units, trucks, tractors and artillery. The use of the trailer, as has been indicated, multiplies the carrying capacity of each motorized chassis, but under war conditions, the auxiliary transport must frequently move through open country, over fields and through woodlands, swamps and sandy soil. It must be able to make sharp turns, to "jack-knife" around trees and stumps, to ride through heavy clay, to cross streams and plow through sand axle-deep, and in general, to serve men and guns with provision and ammunition, to carry water to the thirsty infantryman in the trenches and gasoline to the stalled automobile or aeroplane, to carry first aid to the wounded and to convey the disabled soldier from the field to the hospital, to bring up provender for the stock and telegraph poles for the engineers. It may not be dependent upon motor power alone or upon animal power alone, but must be capable of utilizing either form of power and of rendering the utmost in service for every gallon of gasoline or every horsepower that may be applied at drawbar or pole. In a word it must be easy of draft.

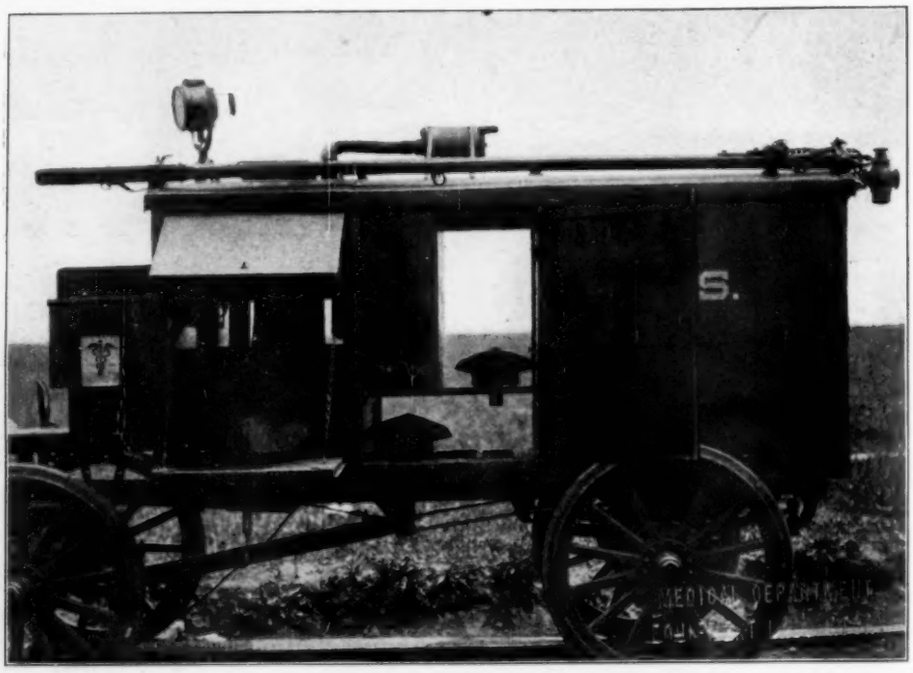
IT MUST HAVE LOW CENTER OF GRAVITY to give stability to the load and it must ride without weave or side-play at all speeds. Provision must be made for perfect alignment when used as a trailer, and general construction must conform to accepted automobile engineering practice as to axles, steering mechanism and wheel construction, including tires.

THE BODY MUST NOT BE INTERFERED WITH BY WHEEL HOUSE OR CUT-UNDER.—The purpose of the universal chassis being to provide for the utmost flexibility of adaptation to the requirements of the various branches of the service, it is obvious that a full-sized, rectangular body platform, capable of carrying field kitchen equipment or ambulance

body or any other type of superstructure must be provided. *The cost must be the lowest cost* measured by service rendered.

To what extent have these requirements been met in Trailmobile Design and Construction?

Manifestly such a set of specifications as those above indicated, expressing the consensus of judgment of qualified members of the War Department, could not be complied with by any manufacturer except through long and patient study and experiment. The problems presented are both of an engineering nature and of pure invention. Their solution has been reached and subjected to the rigid tests of army service in the field. But before indicating the conclusions of the officials under whom these tests were made it may be interesting to army men generally to note just how the more difficult problems were worked out.



Trailmobile as developed at Medical Field Service School, Carlisle, Pennsylvania, for Electrical Field uses

By no means the simplest of these problems to solve was that of providing a short turning radius, to enable the vehicle to respond, without difficulty or danger of upset, to the "jack-knife" turns so familiar to field-seasoned veterans. Like so many of the puzzles that confront the inventor, this one appears so simple as to be almost child's play, now that the solution has actually been found and proved. The front springs, instead of being parallel with the body, are parallel with the axle. A contracted front chassis frame provides space for the driver's seat with tool box beneath it, thus giving the front wheels ample turning angle without in any way interfering with the body proper.

The wheels are of the regulation, anti-friction bearing, motor-truck design with solid rubber tires, a combination that insures ease of draft, ground traction, quietness and protection against the ever-present danger of crystallization of members where metal tires are used on hard roads with motor-driven vehicles. The center of gravity is much lower than that of the stadard escort wagon, giving great stability even when the vehicle is loaded with baled hay or other high-bulking freight. For motor draft the draw bar is attached to the steering plate on the axle, automatically providing correct trailing at all angles and under all speeds. Strength is provided in every feature of the construction which follows the most advanced principles of motor truck design.

From the foregoing it must be apparent that the Trailmobile as developed under suggestions from officers of the War Department not only affords complete interchangeability of parts together with mechanical simplicity sufficient to bring all ordinary repairs within the ability of any blacksmith, but that it follows the lines of commercial development to insure practically unlimited supplies of parts in case of war. For example, the potential capacity for producing wheels of the motor-truck type is growing with the growth of the automotive industry, while the commercial facilities for the manufacture of wagon wheels of the present escort wagon type are dwindling with the passing of the farm-wagon design of animal-draft vehicles. Similarly with practically all essential parts of the trailer, the enormous capacity of the factories engaged in standardized manufacture of automobile parts, gives ample margin of safety upon which the War Department could depend should the nation again be called on to mobilize its industries as well as its man power as in the days of the World War.

Now if the Trailmobile described herein demonstrates its serviceability in actual army field work, to the satisfaction of those upon whom responsibility for efficient transport officially rests (and the reports of the Department of Experiment of the Infantry School at Fort Benning must answer this condition), it cannot fail to interest the officers of practically every branch of the service to consider the possibilities of Trailmobile equipment both as related to their own individual branches and to the War Department as a whole.

For the Quartermaster's Department a universal chassis with universal cargo body, available throughout the entire department.

Rolling kitchens, following the general features of the Trailmobile rolling kitchen, used in such large numbers overseas, both by the Army and by the Red Cross and other semi-official organizations for soldier and refugee aid. Water wagons, both of the single tank design and with equipment for carrying water to the fighting men in containers suitable to the needs of single units where access to the central source of supply is not practical.

For the Infantry and other branches of the srevice a universal escort wagon capable of carrying 20 men or

3,000 pounds of supplies, quickly from place to place, greatly facilitating the massing of troops at strategic points or of bringing up fresh troops to front lines and removing weary and wounded men to the rear. Being equally available for motor draft or for animal draft, such an escort wagon can be used under any condition of road or of terrain wherever there is traction for the motive power unit, whether mechanical or animal.

For the Ordnance, with no change in chassis, a mount for antiaircraft guns and provisions for rapid-fire gun protection, including in the mount the ammunition for both.

For the Signal Corps, equipment for carrying boxed airplanes or for moving complete airplanes disabled through accident or as the result of gun fire. Also a mount for searchlights, etc.

For the Medical Department, ambulance service capable of going into the field or in the woods, wherever mules can get footing. After engagements these units can be coupled together in trains and pulled by trucks to hospital stations. The performance of the Trailmobile in this capacity was effectively demonstrated with the American forces in Europe during the war.

There has recently been designed at Carlisle, Pa., by the Medical Field Service School two important uses for this Trailmobile chassis: A complete mobile electric unit for lighting and field wiring for all medical purposes and for general camp lighting, and with some modification of body equipment, while retaining the standard in parts, this same unit is convertible into a veterinary ambulance.

For the Engineers, a standard interchangeable unit capable of meeting the varied requirements of construction and demolition work in all areas and under all conditions. With Trailmobile standardized lumber bodies these units will prove their serviceability in actual warfare as they have done and are doing every day in the lumber industry of the United States. The Trailmobile lumber units are designed to release the motive unit, whether truck or tractor, for continuous transportation work, with loads one way and returning empty. During the construction of the Marine Corps base at Paris Island one truck regularly drew a train of from three to five Trailmobile lumber units, thus doing in less time the work usually requiring many trucks or an equivalent in animal-drawn wagons.

It would be fruitless to continue the enumeration of uses to which a standard interchangeable chassis of this character could be put in military service. Every reader of this article will think of additional purposes. And with this broadened conception of the "Escort Wagon" there cannot fail to appear the vision of the great economy and the multiplied service that must rebound to the Department as a whole. Complete interchangeability of parts means unfailing supply of repair and replacement parts always available at every base. Mechanical simplicity means freedom from needless demands on the services of engineers and mechanicians. Equipment can be transferred from one branch of service to another in any quantities the conditions of the day may demand; the number of draft animals can be reduced, and the effective continuous operation of motor trucks and tractors maintained. Even the commercial consideration that was primarily responsible for the invention of trailers commends itself to the consideration of the Army officer—I refer, of course, to the conservation of the highways themselves. Every State is enacting laws forbidding the overloading of trucks to a degree that impairs the stability of the roadbeds. To meet this limitation, trailers are absolutely necessary, if the cost and speed of delivery are to be kept where they belong. The military road is even more important and more worthy of preservation than the ordinary highway of peace times. And by distributing the heavy load over six or eight wheels instead of four, the Trailmobile is the first agency for the preservation of the military road.

Trailmobile after road test

What have the official field tests of the standard interchangeable Trailmobile chassis demonstrated?

In a sense this is the crux of the whole matter. Readers of ARMY ORDNANCE are not interested in the engineering or manufacturing problems encountered by the makers of Army equipment, except in so far as their solution has furthered the interests of the War Department. The officers of the War Department who invited the Trailmobile engineers to submit an interchangeable standard chassis according to the specifications suggested as the result of their own technical knowldege of requirements were most exacting, but most fair in their official tests of the product which was finally presented to them. The Infantry School at Fort Benning, Ga., was selected as the base of these tests, which covered months of time and hundreds

of miles of service over roads of every description, through sand and marshes, across swamps and streams at high speed behind trucks and tractors and at low speed behind mules. The vehicle was loaded to full-rated capacity during the entire test. And the final report was, in effect, that the Trailmobile met every reasonable demand that was made upon it.

These reports are part of the official archives of the War Department and are therefore available to those having interest in them through official channels. The photographs that were taken during the tests show that effort was made to disclose every element of weakness and to make every condition more severe, if possible, than would probably be encountered in normal military service. And the net result was that the Trailmobile proved itself capable of negotiating every condition of terrain where the motive unit was able to secure traction. In one test the Trailmobile was hauled into a swampy marshland where the mules sank to their bellies and had to be dragged out. A tractor was then brought around to the opposite side of the swamp, and by means of ropes fastened to the pole, it pulled the Trailmobile right side up and riding evenly on its own wheels to the dry land.

This performance is so noteworthy that it calls for more than passing comment and explanation. The problem of negotiating soft ground with the ordinary type of wheeled vehicle has baffled the ingenuity of engineers both civil and military. In a measure this problem has been solved for units of the caterpillar tractor type by means of the "conveyor-belt" type of self-laying track. The principle is too well understood to call for extended elaboration in this connection. But it remained for the engineers of the Trailmobile to apply this principle to the individual wheels of the four-wheeler. This has been accomplished in what we have named a "Belt Tire." The illustration shows the installation of the Belt Tire on a wheel of the Trailmobile Universal Military Chassis, and some conception of its effectiveness may be gained by comparing the deep ruts of the ordinary escort wagon wheel in the soft ground of a corn field with the compacted surface tread of the Trailmobile wheel with Belt Tire over the same ground, shown in the illustration which is reproduced by permission from one of the official photographs taken during the test.

Such, in substance, is the story of the Trailmobile as developed at the request of the officers of the General Staff and as tested under orders from the War Department. No claim is made that a chassis of this character can be manufactured at lower cost per unit than the standard escort wagon. But the time has long passed when unit cost of manufacture can be accepted as a standard for military equipment. A modern coast-defense gun cannot be made at the cost of a Civil War cannon, nor are the costs of *Monitor* and *Merrimac* of more than historic interest to the naval architect of the present. Efficiency, service, endurance, the utility that is to be secured, these are the only standards that can be used in determining what equipment is to be adopted. And in terms of this kind the Trailmobile Universal Chassis must be judged. Its cost is more than offset by the economies it effects in replacement parts and flexibility of service alone. When to these are added the economies resulting from continuous use of trucks, released from all placement duties, the reduction in the number of draft animals required. the capacity to negotiate terrain hitherto impassable to military wagons, and the innumerable other advantages resulting from its general use, it would seem that in the Trailmobile Universal Chassis there had been developed a unit meeting requirements set and an opportunity afforded to replace a good old servant with a modern and better one.

Road March of First Provisional Ordnance Company

Immediately prior to the graduation of the 1923 class at the Ordnance Specialists School, Raritan Arsenal. it was decided to organize the members into a provisional ordnance company for the purpose of giving the men field training before returning them to their various organizations.

With this object in view, the necessary steps were taken to prepare for a road march, simulating actual field conditions. The men were assigned to duties in accordance with the table of organization covering a war strength ordnance company; the proper matériel was assembled, and on June 1. 1923, at 8:10 A. M., the convoy moved out from Raritan Arsenal, N. J., with Washington, D. C., as its objective.

Stops for the night were made at Sharon Hill, Pa., Aberdeen, Md., and Laurel, Md., the convoy arriving at their parking space in Washington at 11:30 A. M., on June 4.

With the exception of an accident when a truck was rammed by a street car in Philadelphia, only minor mechanical troubles occurred. These difficulties, however, were such as to give the men a fairly comprehensive idea of the problems which arise on a road march, and the experience gained was of no small value.

The company was divided into five sections: Headquarters, service, automotive, artillery and armory. Major articles of equipment were as follows:

Three artillery repair trucks;
Three artillery supply trucks, Load "B";
Three artillery supply trucks, Load "D";
Two small arms repair trucks;
Two Dodge light repair trucks;
Three cargo trucks (3 ton);
Two cargo trucks (1½ ton);
One gas tank truck;
One water tank trailer;
Four Indian motorcycles;
One office truck.

Of the above equipment it should be mentioned that the tab'e of organization calls for ¾-ton trucks in place of the 1½-ton, but as the former were not available it was decided to substitute the latter. The office truck is not authorized in the table to which reference has been made.

During the four-day stop in Washington the organization gave a demonstration of shop work as conducted in the field and took part in two parades which were held during the Shriners' convention.

The convoy started its return trip the afternoon of June 8, and arrived at Raritan on June 11, at 2:50 P. M.

Brigadier General William S. Peirce

The Ordnance Department of the Army lost one of its most valued officers in the death of Brigadier General William S. Peirce, Assistant Chief of Ordnance, who died on July 10, 1923, after a short illness at Emergency Hospital, Washington, D. C.

General Peirce was born in Burlington, Vermont, May 16, 1864, and was appointed to the United States Military Academy from that state, being graduated in the class of 1888. Upon graduation he was appointed an additional Second Lieutenant of the First Artillery and was assigned to duty as Second Lieutenant of the Second Artillery, September 3, 1888. He was appointed First Lieutenant in the Ordnance Department, January 15, 1892, and was promoted to Captain, July 1, 1898; Major, June 25, 1906; Lieutenant Colonel, February 12, 1910; Colonel, April 6, 1915. He was appointed Brigadier General, Ordnance Department, National Army, February 18, 1918, and returned to the grade of Colonel, June 2, 1919. He was appointed Brigadier General, Assistant Chief of Ordnance. with rank from July 1, 1920, and was serving in that capacity at the time of his death.

Brigadier General William S. Peirce

General Peirce was especially well qualified for his important assignment in view of his broad experience in the Ordnance Department. He served tours of duty at the Sandy Hook Proving Ground, Watervliet Arsenal, Rock Island Arsenal, and Springfield Armory. Among other assignments, he served as Inspector of Ordnance at the Midvale Steel Company and several tours of duty in the Office of the Chief of Ordnance, Washington, D. C.

When the United States entered the World War, General Peirce was Commanding Officer of the Springfield Armory, Springfield, Mass. The prompt expansion of the personnel and manufacturing facilities of that establishment and the capacity production of United States Rifles, caliber .30, Model 1903, there, were vital factors in the initial equipment of our Expeditionary Forces. In January, 1918, General Peirce was ordered to Washington and appointed to duty as Chief of the Administration Bureau in the Office of the Chief of Ordnance, an assignment of great responsibility and importance. He performed most valuable services in effecting necessary reorganization of the administrative methods of the Ordnance Department. General Peirce was ordered to join the American Expeditionary Forces in France in July, 1918, for temporary duty, returning to the United States in the fall of that year.

Shortly after the signing of the Armistice, General Peirce was appointed Chairman of the Ordnance Claims Board, in which capacity he rendered most valuable service in adjusting and settling contracts involving over four billions of dollars. He was also a member of the Board to Standardize War Contracts and Adjustments. In June, 1921, General Peirce was assigned to duty as Chief of the Manufacturing Service in which capacity he directed the organization charged with the design, procurement, production and inspection of Ordnance matériel.

General Peirce took a deep interest in the problem of Industrial Preparedness, was an enthusiastic proponent of the policy of decentralized production, and urged the establishment of Ordnance districts for this purpose during the World War. He vigorously supported the logical extension of this policy so as to embrace decentralization of procurement, inspection and other similar functions. He saw clearly that a similar organization would prove to be the most practicable and effective means of securing a proper measure of Industrial Preparedness for the Ordnance Department, and through his initiative and energetic efforts the present existing Ordnance districts were created.

General Peirce received the Distinguished Service Medal for exceptionally meritorious and conspicuous service as Commanding Officer of the Springfield Armory and as Assistant Chief of Ordnance. The French Republic also conferred upon him the rank of Officer de la Legion d'Honneur for distinguished service.

General Peirce was an exceptionally capable and efficient officer of wide attainments, keen perception, sound judgment and broad experience. His deep interest and enthusiasm for adequate preparedness were of great influence. His untimely death is a severe loss not only to the Ordnance Department and to the Army but also to the Army Ordnance Association, of which he was a prominent member and a sincere friend and advisor.

The Role of Chemistry in War

By

H. E. HOWE

SINCE warfare involves essentially the matching of the entire resources of one group against those of another, any science which so directly concerns a large number of national resources as does chemistry must be encouraged within that country which seeks for itself a satisfactory condition for its own defense.

The complexity of our modern civilization serves to emphasize the interdependence of all the component parts of the system as we know it today. It is, therefore, difficult to claim for any one activity distinctive importance above other activities. Each worker feels with some justification that his specialty is the keystone of the arch, forgetting perhaps that any stone removed from the arch would cause its failure. However, those sciences which deal with matter, its changes, properties and applications are fundamental, and it may be truthfully said that no science is nearer the absolute foundation of industrial progress and national defense than is chemistry.

Chemistry might be described as a science which undertakes to devise ways and means for making the matter found in nature better suited to the uses of man, and with such a definition in mind it is relatively simple to think of a great diversity of uses for chemistry in time of war.

It has frequently been said that a nation's most important natural resource is its people, so that in any discussion of resources due attention must be given to the health and well-being of the people themselves. In this most important field chemistry works side by side with medicine, sanitation and other sciences, making possible a state of public health and welfare quite beyond anything conceived a generation ago. This has been due not only to the more skillful application of natural products refined by chemical processes, but to the synthesis of products which are not to be found outside the laboratory, and are deliberately conceived and designed to effect a particular purpose. By this is meant that the chemist is beginning to know how to build up a complicated molecule with atoms selected and arranged so that an attack may be carried out upon the invader of the human body with the destruction of the toxic or pathogenic organism without unduly disturbing that delicate balance of the body upon the maintenance of which health depends. A well-known example of this class of medicinal compounds is salvarsan, and more recently has come tolysin which is said to have all the beneficial effects ascribed to aspirin without the accompanying heart depression. If chemical research in curative medicine is properly encouraged we may see the day when the chemist, upon being given accurate data by the physician concerning a particular malady, will set to work to build a molecule which will cure the disease very much as an engineer now proceeds to build a structure according to plans and specifications.

In industry the advent of war means usually the same type of operations on the same kinds of raw materials, but with a different end product. Thus a shop that has been making automobile specialties turns its lathes and drill presses to cartridge cases and numerous small metal parts for war equipment. War is at best a very wasteful operation, but increased efficiency in production becomes of importance, and we know that production is one of the keynotes of war. Wherever production is involved applied science and particularly chemistry has an important part to play. Certain materials become difficult to find and it is usually chemistry that discovers a way to use some substitute. Because materials must be conserved chemistry and the sciences to which it is so closely related are brought into play to reduce the number of "seconds" or slightly damaged products, to find materials which will increase production, to lengthen the period of service of a machine or of a product, and of course to find ways to meet all sorts of new demands.

We might go through industry and find everywhere abundant examples of what chemistry has done and can do to put plants upon a highly efficient basis, whether this means waste elimination, standardization of raw materials, increased production, better products or lower costs, or even better conditions of labor.

Coming back again to the question of man power it may be said that the training of the chemist serves to make him the corpuscle of the industrial blood stream. When properly trained he is able to discharge a great variety of duties with credit just as the white corpuscle defends the body against intruders and goes to build bone, muscle, brain or nerve as may be needed. There are many examples to prove this assertion, and whether a man practices chemistry or not, the presence of an increasing number of men and women who have had the benefit of a chemical training is very desirable. The conversion of one type of industry into another, as has been suggested in the case of organic chemical industry where certain types of dye plants can be quickly converted to the manufacture of materials of war is not so important as the fact that the peace-time activities of such industries serve to develop the personnel which is able to take on these new duties at a moment's notice. It is in the training of such men and the acquisition of more and more knowledge of fundamentals that the safety of any country lies.

Now while it is contended that the presence of such trained men is beneficial, it is not to be expected that the desirable type of talent can be attracted to the profession of chemistry unless the chemical industry can be encouraged and opportunities afforded for chemical research. The industries in turn make possible the support of chemical laboratories where these men may be trained, and it will be seen that we have possible a strong alliance in which the educational institution, the chemical industry, the research chemist, the public health, national welfare and industrial progress are the important parties. It is believed that any action or policy which serves to curb scientific research necessarily deprives the country involved of knowledge which is vital to its existence in peace time as well as in war time.

German Tanks

By

R. KRUGER

IN November, 1916, when the war ministry had decided upon the production of experimental combat vehicles termed tanks, the technical particulars of the British tanks, which appeared in the theater of war, were not known in Germany. Aside from the fantastic sketches in illustrated periodicals little was at hand, especially regarding running gear. The difficulties which confronted the launching of the project lay principally in the wide limits of changing conditions of terrain. The extent of the adhesion

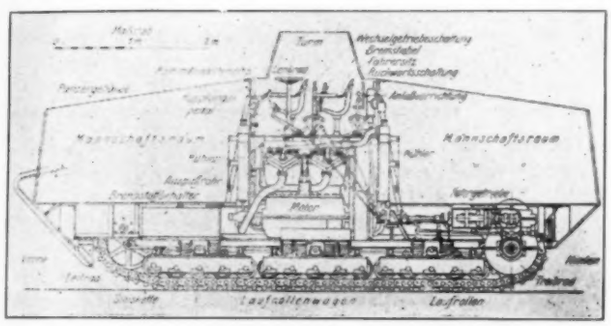


Fig. 1

and bearing power of the soil was dependent on kind and condition of the ground surface and it was concluded that atmospheric conditions must not affect the driving control.

Chief Engineer Joseph Vollmer, prominent in the experimental section of the motor transport inspection service, was charged with the construction of German tanks. It is principally due to his knowledge and experience that several designs for these new vehicles were shortly forthcoming.

The Heavy A.7.V. Tank

In this tank the caterpillar track, which originated in America, was used as the means of propulsion. Due to the indecision of the war ministry concerning the employment of this vehicle, the design of the chassis was evolved for general application: (a) a tank with an armored superstructure, and (b) a cross-country truck and tractor with a platform body for the transportation of supplies.

For use as an armored superstructure, an armored body was sought protecting the upper side of the track against shell fire and providing an increased space for personnel, and when used as a truck or tractor a maximum possible use of load surface of the platform was desired. Therefore, the track was fitted to the running gear, over drive and guide wheels so that it would lie horizontally under the floor of the chassis.

Space for the commander and driver was located in the geometric center of the vehicle over the engine in order to effect convenient steering and to permit observation in all directions by commander and driver alike. An essential simplification for rapid production was visualized in the possibility of the conversion into a tank by merely applying armor plate. Thus safety for the engine space against shell fire was especially carefully provided for.

The entire superstructure of the A. 7. V. Wagon constructed on the foregoing lines is shown in Figures 1 and 2.

Construction of the Vollmer A.7.V. Tank

The roller trucks in pairs are linked together by cross rods independently of the chassis frame, which is suspended on the tracks by spiral springs. Guides connect the track frames with the chassis crosswise and longitudinally. The track drive and guide wheel bearings are integral with the chassis frame, the spring effect of the track rollers being allowed for through the flexibility of the track. The actual contact length of the track is 5 m., for crossing trenches 2 m. wide. Each track has three roller trucks with five rollers each, the center and outer rollers having a spur flange. Tie rods prevent the roller trucks from spreading apart on shifting position, while the upper part of the track is carried on support rollers. Because of uneven wear each track is fitted with an adjustable track take-up. With the tank steeply inclined, sidewise, the flanged track rollers engage in the double track rails, which, in turn, reenforce the track plates laterally and keep the rollers from siding up off the track shoe and thus prevent them from jumping the track.

Each track chain has an internal track rail cast with outer and inner flanges over which the track rollers run. The track links are so built that every track plate is removable. Each track shoe extends over the next one at the joint, so that no opening exists through which sand, mud, or other foreign substances can enter as the track moves along.

There are forty-eight links in each track; the rail portion of the link is 254 millimeters long, inner rail edges 65 millimeters apart; 180 millimeters across outer rail edges; width of shoe, 500 millimeters; thickness, 8 millimeters; horizontal bearing length of tracks 5 m.; bearing area per track, 2.5 square centimeters; flotation for a weight of 25 to 30 tons

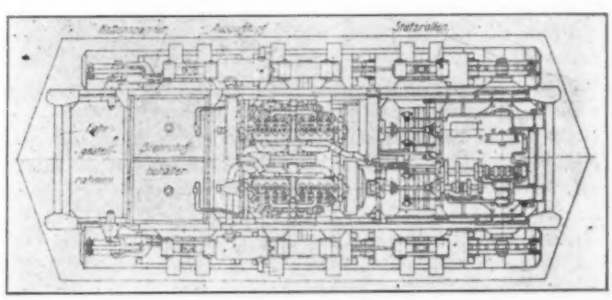


Fig. 2

is 0.5-0.6 kg. per square centimeter; weight per track shoe, 28 kg.; material of track link is pressed steel; track shoes of Siemens-Martin steel; bolts and sleeves are chrome steel.

Steering is accomplished entirely through the two tracks: to turn, the power to the track on the inside of the turn is slowed down or stopped by a brake according to the radius of the turn desired, while the drive to the outside track continues. The minimum turning radius is 2.2 m., which equals the span between tracks. To turn in place about the

axis of the vehicle, one track can be run backward and the other forward. Turning about the vertical axis through an angle of 360 degrees is therefore possible. Slight curves while traveling over traffic routes are made by changing the relative speed of the two driving engines. A slight movement of a hand wheel varies the engine speed required for such a turn.

A separate steering mechanism with two clutches as in a single engine drive becomes superfluous as a result of using two driving engines. The steering clutches K and L, shown in Figure 3, are also the engine clutches, each of which is driven by the prolonged crankshafts A and B, respectively. The driving and steering mechanism is a separate unit for each track and both units are placed together in a common housing. Each transmission has three steps of speed reduction for 3, 6 and 10 km. per hour. The gears E, F, G keyed to the clutch shaft can be shifted by a hand lever to mesh with respective pinions E_1, F_1, G_1, which actuates a jack shaft W, carrying opposing reduction bevel pinions. The

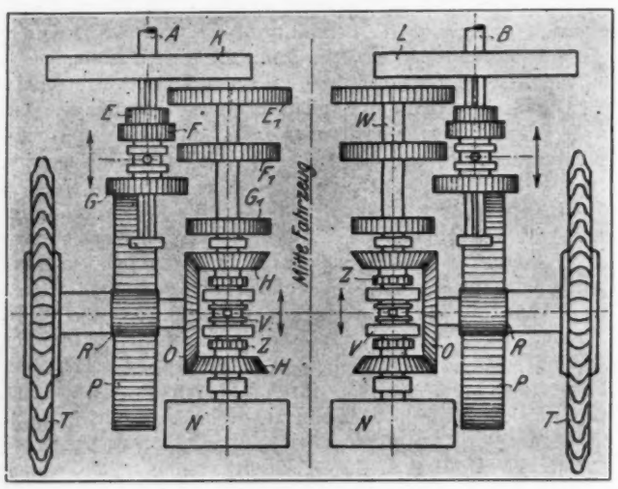


Fig. 3

bevel gears H are engaged by a sliding tooth coupling Z for driving forward or reverse. The driven bevel O drives the track sprocket T through the reducing gears R, P, in either direction, according to which bevel pinion the sliding collar V engages.

From the driver's seat one track can be coupled to run forward and the other backward, so with this arrangement the tank can be spun around. By engaging both transmissions to run alike, movement of the tank straight ahead is effected; by disengaging either one for turning and with both out, the tank stops. Each engine clutch is of the double cone friction type, which design affords engaging or disengaging without great exertion. Two brake drums, N, are set on the rear extensions of the two transmission shafts. By means of them either or both tracks can be braked or the tank brought to a stop on sloping ground. Appropriate levers for all manipulations are installed at the driver's seat.

An engine delivering at least 200 h. p. was required to obtain a vehicle speed of 10 km. per hour, and the production of such a powerful engine was difficult at that time. It was also difficult to find an easy working clutch for a positive transmission of 200 h. p. On this account the producer decided upon the use of a dual motor system. Units of 100 h. p. suiting requirements were soon available.

As shown in Figure 2, the engines were set close together and had their manifolds so placed that the intake pipes were on the outerside and the exhausts adjacent on the inner side, thus avoiding the detrimental heating of the intake of one engine by the hot exhaust gases of the other.

The engines were four cylinder type, having 165 millimeter bore, 200 millimeter stroke, and rotative speed of 800-900 revolutions per minute. Each engine has a true three-point suspension on the chassis.

A magneto with impulse starter was used for the ignition.

That the proper level of fuel remained constant in the carburetor with the engine greatly inclined had to be considered for each separate in-take system.

It was necessary to so arrange the lubrication that no flooding of the rear cylinders occurred with the engine inclined at 45 degrees. This was provided for by the addition of a special oil sump into which oil collecting in the crank case was pumped back and thence strained and redelivered to bearings by a second pump. These measures prevented the engine from splashing oil and fouling the spark plugs due to excessive lubrication. A throttle set for a given maximum revolutions per minute provided the control of the engine. A hand lever at the driver's seat operated the throttle to control the engine speed down to the lowest speed.

The starting of these relatively large engines due to inferior fuel caused great difficulties, especially in winter. On this account various types of starting devices were used such as:

(a) Priming pump.
(b) Electric starter.
(c) Bosch atomizer.
(d) Three-man hand crank.
(e) Acetylene.

When one engine was started it could start the other one by connecting in the transmission and starting the tank.

Each vehicle was fitted with a lighting generator for illuminating the interior of the tank and for night driving of the tractor truck. In order to regulate the proper engine speeds a tachometer was connected with each engine.

The fuel was carried in two containers of 250 liters capacity, which were installed in the forward part of the chassis. These were protected from shell-fire on the bottom by armor plate 10 millimeters thick, and on the sides by the chassis frame and hull armor plate. Each container was separately connected to both engines. The fuel tanks were covered on top with sheet iron to reduce the fire hazard, thus to prevent the danger to occupants of the vehicle in case the contents of the tank caught fire.

Two auxiliary tanks near the driver's seat were provided in case both main tanks were out of commission.

Two large tubular radiators at either end of the engine housing provided the cooling for the motors. They were loosely held in two felt-lined jackets suspended above by elastic brackets. The housing held the radiators vertical.

Four fans provided the ventilation of the radiators, each pair being driven from the flywheel end of one engine by wide detachable belts. The fans driven from the engines sucked the air from the interior of the tank through the radiator.

TABLE I

DATA ON THE HEAVY GERMAN TANKS

Net weight of chassis, including fuel, cooling water and tools	16,000 Kg.
Armored hull	8,500 "
Personnel, 18 men	1,350 "
1 5.7 quick-fire cannon, 5 machine guns, with ammunition, etc	3,500 "
Engineer tools and so on	650 "
Total weight of 1 tank	30,000 Kg.

Engine power, 200 h. p.; r. p. m., 800-900.
Tractive power, first speed 3 km./hr., 15,000 kg. (Due to the long contact of the track on the ground the tractive power can be increased to equal the bearing weight with a selection of gear reduction to correspond therewith.)
Tractive resistance on sandy soil at 6 km./hr., 85 kg./ton.
Tractive resistance on sandy soil at 10 km./hr., 110 kg./ton.
Cross country grade climbing power 1:3.5 (dependent on the gear ratio of the first speed).
Ability to cross trenches and ditches 2 m. wide.
Ground pressure, 0.5-0.6 kg./sq. cm.
Clearance on all German, Belgian, and French railways with driver's cab lowered.
Cost of production of one tank, about 250,000 marks, of which 100,000 marks for armor plate (from quotations for 1917-18).

The A.7.V.-U Tank (Vollmer Design)

As the construction of the A.7.V tank progressed, the mechanical details of carrying the track around the periphery of the hull were also worked out on an experimental model. Such a vehicle, designated "A.7.V.-U wagon" (U-peripheral track) was produced. It followed the British tank design as illustrated by Figure 4.

This model differed from the A.7.V. wagon mainly in that the armored hull and chassis were combined and the track was carried up higher in front, the profile of the tank was of rhombus shape, and the driver's and commander's seats were not placed over the engine space, but set up at the front of the vehicle.

Equipped with two 5.7 cm. quick-fire cannons and three machine guns, and having armor plate 20 mm. thick, the total weight of this tank came to 40,000 kg. It crossed trenches 3-4 m. wide. The other characteristics of this tank followed, in general, those of the A.7.V. model.

The Light L. K. I and II Tanks

After the advent of the first A.7.V. tanks the military authorities at Grand General Headquarters at Mainz decided (May, 1917) to organize more units of heavy tanks. The designer of the A.7.V. tank, however, was clearly convinced

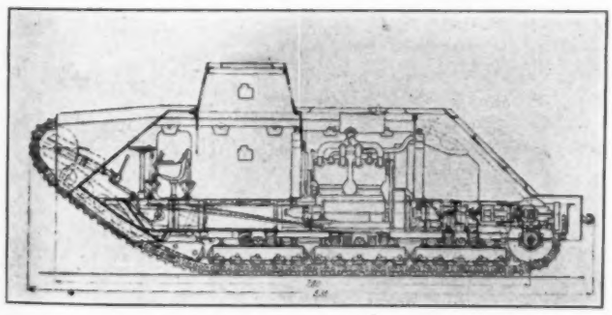


Fig. 4

that the employment of this tank, due to its size, weight, and performance, was limited and that pursuit could be accomplished only with a large number of small tanks.

Independently of the influence of military headquarters, the basic idea for the construction of a light tank (L. K. wagon) for one driver and one or two gunners was drawn up and the project submitted in September, 1917, and approval was granted to produce two experimental tanks, which received the designation L. K. I.

It was decided to use the installation of machinery of available automobile factories to speed up production. There were at hand over 1,000 so-called benzine and air motors of 18/40 to 25/60 h. p. stored in motor transport warehouses. Series of fifty units or more could be assembled and with available reserve and necessary repair material, were found suitable for this design. The chief difficulty of construction lay in the limitation of the total weight to permit the use of this engine. The automobile chassis, after removal of the wheels, was installed intact into the tank running gear frame as shown in Figure 5.

For propelling the machine, two track drive sprockets were substituted for the rear wheels. In place of having

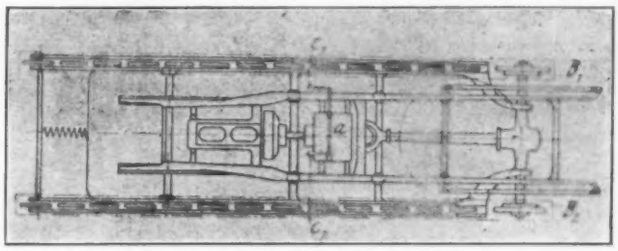


Fig. 5

the front steering wheels the track was fitted with a modified transmission for steering. The normal brake bands B_1, B_2 to which the track drive sprockets were attached, were each connected to brake levers C_1 and C_2, respectively. By this arrangement, on braking one track, the differential operated to speed up the other track, and thus effect steering of the vehicle as desired. Thus the retention of the above mechanism fulfilled the requirements of track transmission.

The normal auto chassis A was connected to the auxiliary frame by its forward and rear springs as well by an extra spring set between them where needed so that the whole was well suspended for obtaining greater speed.

Besides this the supporting and guide rollers could be spring-suspended to the auxiliary frame so as to increase their durability. The following objectives concerning the design as shown in Figure 6 were considered:

1. The vehicle as a whole must be transportable on all ordinary flat cars with sufficient clearance, on unloading, to be able to get under way. Weight as low as possible, not over eight tons.

2. Speed of 12-15 km./hr. over even ground and medium hard soil. Climbing power up to 45 degrees for short distances.

3. Safe positive running engine, which would not smoke up and which would run freely in any way on all slopes up to 45 degrees.

4. Spring-suspended track: Cantilever across trenches 2 m. wide. The track profile to be such that it always bears evenly with the tank tilted forward or backward. Débris into which the tank might plunge must not be able to clog the track.

5. Proper distribution of weight: The armor must protect the crew; armament, motor and running gear must be proof against armor-piercing infantry ammunition at normal impact (about 14 mm. armor plate.)

6. Armament: One 5.7 cm. quick-fire cannon, with 120 rounds of ammunition. For defensive action a light machine gun would suffice but was not provided. On all sides, pistol holes which could be closed.

7. Crew: One driver and two cannoneers.

8. The armored rear wall should be so shaped as to protect the gunners from rifle bullets and bombs. On the rear end a strong towing hook to hitch on light cannon or mortar.

9. Further military requirements are:

(a) The vehicle must present the lowest possible target.

(b) Greatest possible clearance, underside closed and smooth.

(c) Possibility of crushing wire entanglements without any part of the vehicle snarling it up. Track carried up high in front.

(d) Good means of clearing dirt out of the track.

(e) Bearing pressure not over 0.5 kg. per sq. cm.

(f) Great flexibility in turning, to dodge artillery registration by pursuing a zigzag course.

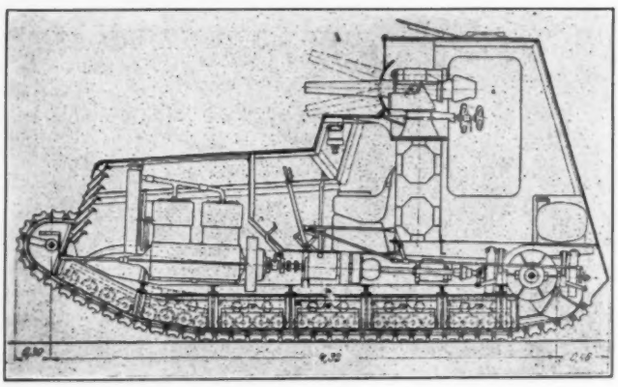


Fig. 6

(g) Easy accessibility of all parts, particularly easy and quick replacement of engine parts throughout.

(h) Continuous running of engine under full load for six hours without refill of reserve fuel.

(i) Greatest possible safety against fire. Fuel containers not to be in crew space.

(k) Quiet running (motor, transmission, and caterpillar track).

(l) Strong towing brackets fore and aft.

(m) Fighting compartment not too cramped and with best possible ventilation. Possibility of opening large hatches easily and quickly by the crew during pauses for observing, and to enable the crew to get in and out quickly.

(n) Attention paid to the shape of eye slits and loop holes for protection against lead splash. Possibility of entire immunity of all openings against flame projector attack.

It was now a question of a new class of caterpillar tractor under Patent No. 311169 with track roller trucks carried in a track frame. Each track independently of the other was carried around between a pair of vertical main chassis side walls of parallelogram shape and could adapt itself slightly to uneven ground surfaces. The track roller trucks were held transversely and in trace by the parallel walls of the track frames and at the proper distance from each other by the lateral track-frame braces or by links. The understructure and track roller truck housings were thus combined, forming a rigid system. The necessary belly clearance was also obtained. The axles of the track drive and guide wheels were set in bearings supported by the track frame side walls; the guide wheel being adjustable by means of set-screw bolts for tightening the track. Spiral springs bore the frame on the rollers so each track was elastically suspended. The forward part of the track was curved up in front to climb logs, ditches, etc. The effective length of the track for crossing trenches was 5 m., while the bearing length of the track was about 2.8 m. The side view of the track resembled a flattened triangle, the top track return forming the longest side of the triangle. The track frames were each provided with five spring-suspended roller trucks and one fixed truck. The fixed trucks were placed in front and worked only for climbing across trenches and the like. The other trucks each had four rollers. The rollers were cast with spur flanges to prevent them slipping sidewise and the side plates of the roller trucks extended down with clearance on either side of the track rails which would prevent the track from slipping off sidewise when the vehicle was listed sharply even when the track rode up clear of the roller-spur flanges.

The kind of chain track used for the A.7.V. wagon, although of smaller dimensions, was favorably considered for this tank. Reduction in the gross weight and number of track plates was thus made possible and, as a consequence, influenced to a marked degree the running of the track at high speed.

There were 148 track plates to each vehicle; the track plates were 140 mm. long; space between track rail, 27 mm.; outside width across rails, 80 mm.; width of plate, 250 mm.; thickness, 6 mm.; horizontal bearing length of the trackway about 2.8 m.; the bearing surface of both tracks on soft soil about 1.4 sq. m.; ground pressure for a gross weight of 8.5 tons equals 0.6 kg. per sq. cm.; weight per track plate, 2.85 kg.; material of chain links, pressed steel; material of shoes, Siemens-Martin steel; material of pins and bushings, chrome steel; tensile strength of track, 30,000 kg.

Steering was effected in this case exclusively by means of the two tracks. By operating the right-hand lever, turning to the right resulted. The drive to the track lying on the inside of the turn was thus interrupted and free running of this track braked to the amount necessary for the desired turning radius, so that only the drive to the track lying on the outside of the turn continued to work. To turn to the left, the left-hand lever was operated in a like manner. The minimum turning radius was 1.7 m. despite the large contact of the track.

To retain the method of operating the vehicle to which drivers of ordinary motor cars were accustomed, the automobile chassis comprising engine, foot clutch, gear shift

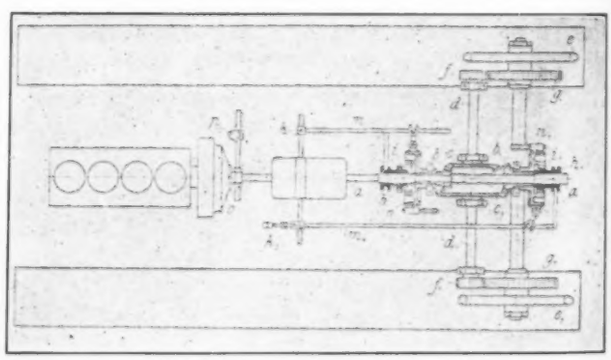


Fig. 7

and transmission brake were left unaltered and the steering mechanism connected with the track drive wheels was the only special feature. A reduction drive was interposed between the driving and steering mechanism to raise the tractive power for climbing 40-degree slopes, the total gear reduction being further reduced by the ratio of 1:2. In normal driving over difficult deficient terrain the reduction drive was interposed and quickly enmeshed by operation of a hand lever. The speed and gear reduction ratios are summarized in Table II, which follows.

Figure 7 illustrates the layout of the steering mechanism. Disc clutches are used in actual practice.

The driving bevels b and b_1 run free on the main drive

TABLE II—L. K. II POWER AND SPEED RATIOS

Engine	Rating Normal Power R. P. M.	25/55 H. P. over 22 rated H. P. 50 H. P. at 1400 r. p. m. 1400—1800			
	Speed Setting	I	II	III	IV
Travel speed km	Without reduction gear—Normal	1:1.53	1:2.2	1:3.45	1:9.1
	Without reduction gear—Maximum	3.5	4.7	7	14
	With reduction gear—Normal	4.5	6.0	0	18
	With reduction gear—Maximum	1.62	2.17	3.35	6.5
Gross tractive power, kg	Without reduction gear—h = 0.8	2.10	2.80	4.20	8.4
	With reduction gear — h = 0.72	3000	2250	1500	750
Normal pull, each drive wheel	Without reduction gear	5900	4400	2950	1450
	With reduction gear	2100	1575	1050	525
		4150	3100	2100	1050
		Weight of tank 8.5 tons			
Climbing power	Without reduction gear—Per cent	30	21.5	12	3
	Without reduction gear—Degree	17.5	12.5	7	2
	Without reduction gear—Slope	1:2.3	1:4.64	1:8.35	1:33.3
	With reduction gear—Per cent	65.5	45.5	29	11
	With reduction gear—Degree	41	27	17	6.5
	With reduction gear—Slope	1:1.53	1:2.2	1:3.45	1:9.1
Gear ratios	Direct drive	1:4	1:3	1:2	1:1
	Reduction gaer		$\frac{16}{26}\ \frac{18}{24}$ =1:2.17		
	Touring drive		$\frac{18}{60}$ to $\frac{21}{70}$ =3:10		
	Final drive (fg)		$\frac{16}{48}$ =1:3		
Total reduction	With reduction gear	1:40	1:30	1:20	1:10
	Without reduction gear	1:87	1:65	1:43	1:22
Track sprocket	Radius 271 mm	Pitch 140 mm			Teeth 12

shaft a. These mesh with bevels c and c_1 on the cross jack shafts d and d_1, respectively. These shafts transmit power to the track drive sprockets e and e_1 through pinions f and f_1, meshing with gears g and g_1. The dog clutches h and h_1 are keyed to and slide on the main shaft a, and can engage the recessed clutches i and i_1 integral with the driving bevels b and b_1, so that the power can be applied or interrupted to either side or both. Shifting of the dog clutches is effected by the hand levers k and k_1 through connecting rods m and m_1.

Figure 7 shows hand lever k_1 in the forward position with its dog clutch engaged, hand lever k in the mid-position with its clutch disengaged. Attached to drive bevels b and b_1 are the brake drums n and n_1, which can be held from turning by brake bands to steer the vehicle, and are likewise operated by the hand levers when the latter are drawn back beyond their mid-positions.

The engine clutch o must be disengaged by pedal p before operating the hand levers k ank k_1 which shift the dog clutches to couple or uncouple them as shown. The engine clutch must be engaged again when either brake is applied.

By using friction clutches in place of positive dog clutches, turning could be more easily effected by merely operating the hand levers either of which when pulled back interrupted the drive to its corresponding drive bevel, and further movement of this lever to the rear applied the brake to this same side.

Only an intermediate cross shaft providing two steps of power reduction beyond the clutches and brakes was installed to carry the entire mechanism and proved to be satisfactory. The clutches and brakes had to be placed on the longitudinal shaft because of the greatly contracted lateral space available in such vehicles.

The reduction gears driving the track sprockets on either side were incased in housings which were fastened to a rear closed-off wall of the chassis and rigidly supported the axles carrying the large gears and the track sprockets. The outer track frame wall held the outer axle bearing so that the tractive power to the track was transmitted to each track frame independently.

Since the friction of the track driving mechanism amounted to between 55 and 110 kg. per ton due to the type of self-laying trackway adopted, a large truck engine, as given in the table on power ratios, was needed to impart an average speed of at least 14 km. per hour to a tank weighing

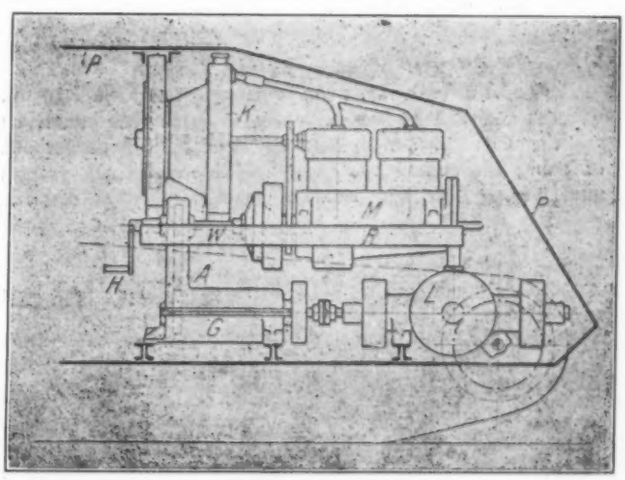


Fig. 8

8.5 tons. With auxiliary reduction drive it could negotiate 41-degree slopes at a speed of about 1.6 km. per hour. Special features needed for such a climbing power comprised an alteration of the float chamber for maintaining the normal fuel level in the carbureter when greatly inclined and provision of a lubricating system with an oil pump to prevent flooding the rear cylinders with lubricating oil.

These adaptations could be easily substituted on most engines, and all remaining features could be retained unaltered. Starting of the engine was effected by cranking from the front end of the vehicle or by a crank device inside as well as by an electric starter.

Fuel was contained in two tanks having a total capacity of 140 liters which were placed on either side forward between the armor hull and engine to lessen the fire hazard. To protect these tanks from shell fire their bottoms were covered by a plate 8 mm. thick. The pressure of the exhaust provided the means of forcing the fuel to feed.

The cooling system for the motor had to be somewhat modified. By installing an exhaust fan (instead of the usual fan) the cooling air was drawn from the interior of the hull and the heated air exhausted the shortest way up through louvres in the hood plates. The temperature inside the hull was thus automatically maintained at about that of the temperature.

TABLE III

WEIGHT DATA ON THE L. K. II TANK

Chassis without running gear	1,700 kg.	
14 mm. armor plate walls, 8 mm. hood and bracing	2,100 "	
Iron hull frame	500 "	
Machinery and steering gear	1,800 "	
Caterpillar track	900 "	
Track roller trucks	650 "	
Track tension idlers	50 "	
Gross weight of tank	7,700 "	7,700 kg.
Fuel and cooling water	150 kg.	
Crew of 3 men	225 "	
2 machine guns	100 "	
Ammunition	250 "	725 "
Total weight of vehicle equipped for field service		8,425 kg.

The total weight would be increased with 5.7 cm. cannon, weight 500 kg., and 100 rounds of shot, 450 kg., by the difference compared to 2 machines with ammunition.

The cost of production from prices quoted in 1918 amounted to 65,000-70,000 marks per vehicle.

The Light L. K. III Tank

The L. K. II tank was a compromise to which the builders were forced due to the difficulty of procuring materials and the short time set for delivery, but especially on account of using the chassis mentioned. The same track frames and steering gear were retained practically intact, also the automobile chassis inside the L. K. II tank described, so the new design comprised principally the arrangement of the power plant to meet whatever requirements should be decided upon.

In one light L. K. III design the engine was placed in the rear of the vehicle over the steering mechanism L and the transmission gear box G. The engine M could be supported either on brackets cast on the transmission housing or else on a frame so that in either case the engine had a three-point suspension or nearly so, as in Figure 8.

The engine cooling system K was also set on the frame R, thus requiring no displacement of the water pipe connections leading to and from the engine. This suspension of the engine M and cooler K as a unit independently of steering mechanism and transmission G and L and hull P, obviated its exposure to the detrimental warping action of the track frames and so was an important factor in preserving its durability. Power was transmitted from the engine clutch W to the speed gears by means of gears or tooth chain running in a housing A cast on top of the gear case G. The hand crank H, with ratchet, set in the housing A, engaged the clutch shaft W for starting the engine.

The great advantages of having the various parts of the machinery in separate units independent of any distortion of the chassis or hull as well as their ease of manufacture need no further comment.

The driver's seat was still placed in forward part of the hull, the driving and steering levers and the clutch and brake pedals within easy reach. The fighting compartment lay between the driver's seat and engine space. One machine gun or one 5.7 cm. quick-fire cannon was mounted in a turret having all around traverse.

A comparison of this model of the German tank with the English and French models showed a remarkable similiarity of opinion and knowledge of underlying principles in many particulars, at a time when in Germany the details of design, especially of enemy light tanks, were entirely unknown.

Of the German tanks only a dozen or so of the A.7.V. Model got into action. A few experimental models only of the light tanks were ever completed.

Compared to the English tanks the German A. 7.V. tank had great strength and fighting power; its caterpillar tracks were better protected than the tracks of the English tanks which ran exposed around the entire hull. The latter, however, due to this arrangement could better negotiate obstacles, but at the same time were more exposed to damage.

EDITOR'S NOTE.—The above article was translated from the German by Capt. William E. Lucas, Jr., U. S. A. Tank School, Camp Meade, Maryland.

Who Invented the Tank?

Credit for the invention of the armored caterpillar "tank" as an instrument of warfare is denied to the British and conceded to the Teutons by the United States Patent Office. If the Patent Office record is correct it adds one more to the mistakes attributed to the Germans in their conduct of the war, for the shock the Germans got when the British tanks appeared in battle did not come until five years after a German patent had been taken out on a similar death-dealing machine.

"Records of the Patent Office," says a Patent Office statement, "showed that Gunter Burstyn, of Austria, was granted a German patent on a caterpillar tank on February 22, 1912, which is practically a duplicate of the English type used in their offensive during 1917 and 1918.

"Drawings of this German tank reveal the fact that it was so constructed as to crawl over trenches, plow through wire entanglements and perform all the other feats that made the English tank so successful in the War.

"Having issued a patent upon an armored tank of the caterpillar type in 1912, it is puzzling to understand why the German Imperial Government did not make use of it during the war, instead of allowing the English to surprise them with this new engine of destruction. (*From the New York Times, April 23, 1923.*)

Jump

By

A. B. WHITTET *and* D. A. GURNEY

EXTERIOR BALLISTICS treats of the motion of the projectile after it has left the piece, and therefore includes the effects of "Jump." Jump has been defined as the difference between the angle of departure of the projectile and the angle of elevation of the piece, and it was the accepted theory that it is caused by the movement of the axis of the piece while the projectile is in the bore. Recent studies have shown, however, that the yaw of a projectile as it leaves the bore causes some of the difference.

The movement of the axis of the piece is permitted by clearance between piece and cradle, trunnion beds, and the elasticity of the parts of the carriage. In some cases the movement is caused by the action of the elevating device while the piece recoils, but in most mobile artillery mounts the movement is due to the action of powder pressure eccentric to the center of gravity of the recoiling parts and the pull of the recoil controlling device.

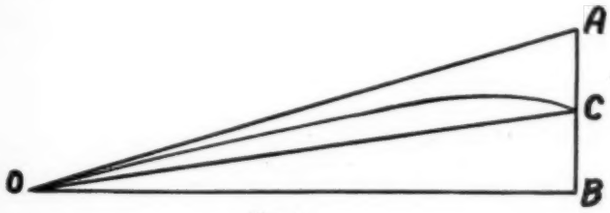


Fig. 1

For the purpors of correcting firing tables, jump is should not also be used to describe the vertical rise of mobile carriages which takes place while the piece is recoiling and counter recoiling, if instability obtains; and since "jump" has been pre-empted for the other use, this vertical movement of the carriage itself might well be called "hop," since the word is so similar in meaning to the word "jump."

For the purpose of correcting firing tables, jump is determined experimentally for the particular cannon and carriage under consideration and for each muzzle velocity and kind of projectile to be used. It is measured at the Proving Ground by bore-sighting the piece on a spot on a cardboard target at a known distance from the muzzle, firing the projectile through the cardboard at that elevation, measuring the distance from the spot to the center of the hole made by the projectile, correcting this distance for the action of gravity from muzzle to target, then converting the measurement to angular measure. Thus, the muzzle velocity, or time of flight from muzzle to screen, should be known, and consequently jump is usually measured on the rounds fired for obtaining the average muzzle velocity of a group of range rounds. In some cases where jump is being very carefully investigated, steps are taken to determine the time of flight from muzzle to the cardboard target.

In Fig. 1, let AB be a vertical screen placed at such a distance from the gun muzzle O that it will not be affected by the blast. Let OB be the axis of the bore, supposed horizontal. The point B, where the axis of the bore prolonged pierces the target, is found by means of bore sights. When the gun is fired, let OA be the line of departure. Then AOB is the angle of jump. The projectile will strike the target at some point C, and CB can be measured.

$$\tan \text{AOB} = \frac{\text{AB}}{\text{OB}} = \frac{\text{AC} + \text{CB}}{\text{OB}}$$

From the laws of falling bodies we have $\text{AC} = \frac{1}{2} gt^2$.

For the short distance OB we may regard the velocity of the projectile, v, as uniform.

$$\text{Let OB} = a \qquad a = vt;\ t = \frac{v}{a} \qquad \text{AC} = \frac{ga^2}{2v^2}$$

$$\text{Let CB} = b \qquad \tan \text{AOB} = \frac{ga}{2v^2} + \frac{b}{a}$$

If OB is not horizontal, the same principle applies, the triangle AOB being oblique instead of right angled.

The solenoid chronograph recently developed has made it practicable to record the muzzle velocity of each round fired for range data and it has also facilitated the process of investigating jump characteristics at high angles.

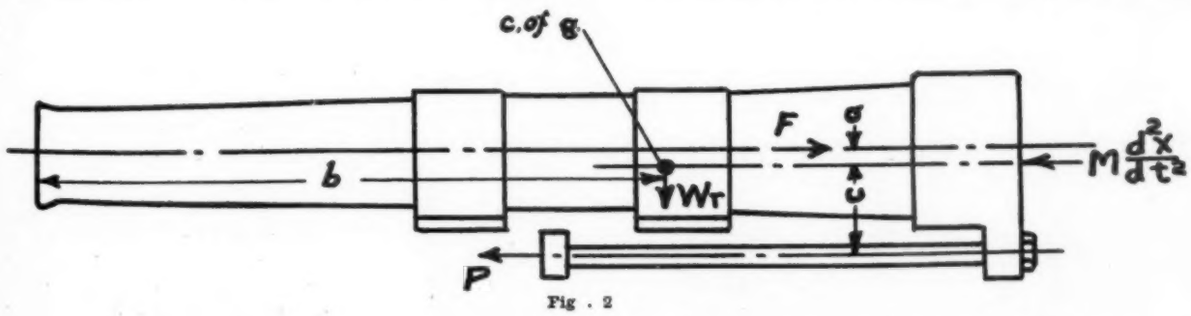


Fig . 2

Jump can be investigated theoretically, by calculations, and when compared with the value of jump as determined experimentally the calculations are found to agree very

closely. The process is lengthy, but not at all difficult, since it merely involves determining the weights, moments of inertia, etc., of a given construction and applying the laws of mechanics. The method will be exemplified below.

However, it is not necessary to complete the whole process of computation, if, for instance, the relative merit of two designs of carriages is under consideration, for in such a case it would be sufficient to calculate what the maximum jump could be, if the recoiling parts were free to rotate, without other restraint than the piston rod pull.

Refer to Fig. 2, where—

t = time the projectile is in the bore ---------- = seconds.
Θ = angular movement of axis of piece in time t ---------- = radians.
F = average total powder pressure ---------- = pounds.
P = average piston rod pull during time t ---- = pounds.
M_r = mass of recoiling parts.
K = radius of gyration of recoiling parts around center of gravity ---------- = feet.
M_rK^2 = Moment of inertia of rotating parts, axis through center of gravity.
a = distance from center of gravity of recoiling parts to center line of bore ---------- = feet.
b = distance from center of gravity to muzzle = feet.
c = distance from center of gravity to line of action of P ---------- = feet.
$\frac{Md_2^{\,x}}{dt^2}$ = inertia force of recoiling mass = F — P = pounds.

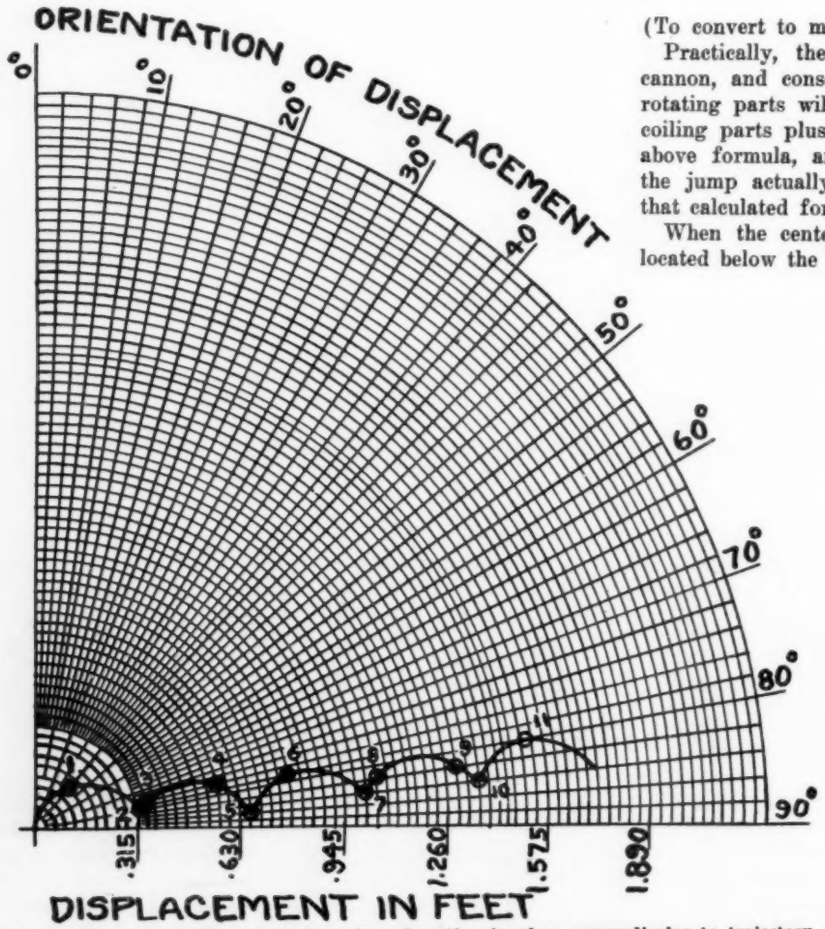


Fig. 3. Displacement due to yaw and its orientation in plane perpendicular to trajectory. Points indicate intervals of 100 feet; twist of gun, 1 in 20

u = angular velocity of recoiling parts at time t ---------- = radians/seconds.

If we assume that the recoiling parts are free to rotate, that is unconstrained by the guides on the cradle, we may by inspection, write:

$$\Theta = (Fa + Pc)\frac{t^2}{2M_rK^2} \text{ radians, and } u = \frac{2\Theta}{t}$$

At this instant the vertical velocity of the muzzle and the projectile is:

$$V_r = ub - \frac{2\Theta b}{t} \text{ ft. per second.}$$

The tangential velocity of the projectile at this instant $= V_m$ = muzzle velocity in feet per second.

The jump due to the vertical velocity is:

$$\phi = \frac{V_v}{V_m} = \frac{2\Theta b}{tV_m} \text{ feet/second (assuming that since angle is small it is equal to its tangent).}$$

The total jump then is equal to:

$$(1)\quad \Theta + \phi = (Fa + Pc)\frac{t^2}{2M_rK^2}\left(1 + \frac{2b}{tV_m}\right) = \text{radians.}$$

(To convert to minutes multiply by 3438.)

Practically, the cradle does impose reactions on the cannon, and consequently the moment of inertia of the rotating parts will be greater for the combination of recoiling parts plus the cradle than the M_rK^2 used in the above formula, and therefore, it may be expected that the jump actually measured will generally be less than that calculated for the free recoiling parts.

When the center of gravity of the recoiling parts is located below the bore as indicated in Figure 2, the jump should be upward or positive; if above the bore the sign of a becomes negative, and if the product of Fa exceeds the product of Pc, the jump should be downward or negative. In some cases, the center of gravity of recoiling parts may be above the bore, and P may also act above the piece in which case Fa and Pc are both negative, hence the jump should be downward or negative.

The above analysis has been made on the assumption that the center of gravity of the recoiling parts is in the vertical plane through the axis of the piece, which sometimes is not true, as the weight of breech and piston rods and their pull may not be symmetrically disposed about the vertical plane through the axis of the cannon. In this case the moment of the powder pressure would have a tendency to cause some deflection of the recoiling parts laterally as well as vertically, hence the corrections for deflection that are given as

"draft" in firing tables include this lateral jump as well. Recent tests of experimental matériel have shown that this lateral jump should be given due consideration when studying the comparative characteristics of cannon and carriages as to range and accuracy.

It is good practice to design a gun and carriage so that the distance from center of gravity of recoiling parts to center of the bore is quite small (about 0.1 inch) so that the moment of powder gases $F \times a$ will be as small as practicable and tend to produce positive jump; consequently, even though the total powder pressure may amount to thousands of pounds, the jump will be only a few minutes in magnitude. For this reason lost motion in the elevating mechanism should have little, if any, effect on the jump, when the trunnions are located near the center of gravity of the tipping parts because the lost motion in a new carriage due to necessary working clearances and manufacturing tolerances may exceed the total jump to be expected without any restraint from the cradle at all. A thorough test of the 3-inch Field Gun and Carriage, Model 1902, at Rock Island Arsenal and Sandy Hook Proving Ground to investigate this theory proved it very strikingly.

The average elevation lost motion of new carriages of this model was 2 mils = 6.75 minutes, while for several carriages that had been in service for some time it was about 20 minutes. The trunnions are located at the center of gravity of the cradle. Range table data compiled from firings made on a comparatively new carriage showed the jump to be 5.7 minutes at 0° elevation and 7.7 minutes at 25° elevation. Firings were made at Sandy Hook Proving Ground on a carriage arranged so that there would be no restraint to rotation of the cradle about the trunnions while the projectile was in the bore. Under this condition the jump was found to be 9.63 minutes at 0° elevation and 7.8 minutes at 25° elevation. The calculated jump from equation (1) above is 10.61 minutes at all elevations. This difference of calculated and measured jump was attributed to errors in assumptions in making the calculations and the effect of yaw of the projectile. From these firings it was concluded that "the elevating and traversing mechanisms have little, if any, influence on the magnitude or direction of jump" (O. O. 37664/4550).

In recent years there have been extensive investigations of the flight of projectiles along the first thousand feet of the trajectory to study the effect of yaw on range and accuracy. These experiments have shown conclusively that the axis of a projectile after it emerges from the bore, becomes inclined to the trajectory and the orientation of the inclination revolves, and this in turn displaces the center of gravity of the projectile from the theoretical trajectory a certain amount, vertically as well as laterally, and the displacement varies in cycles, which, in turn, vary in period and amplitude for the different forms of projectiles, velocities, rates of spin, etc. Consequently when jump is determined experimentally while range firing at a certain screen distance for a given set of conditions, it will be found that if measured at another screen distance, a different amount of jump will result. This is strikingly illustrated by Figs. 3 and 4, which show the locus of the displacement of a 3.3-inch projectile fired through a distribution of cardboard screens from about 40 feet from the muzzle to about 1,000 feet from the muzzle as projected upon a plane perpendicular to the theoretical trajectory. The projectiles used in the test were of special shape. The locus in Fig. 3 was derived from a gun having a twist of 1 in 20 while the other was for a twist of 1 in 15. Figure 5 shows the actual screens obtained by firing another 3.3-inch projectile. Note the rotation of the projectile axis.

In certain mobile carriages of recent design having maximum elevation of 45° or more, it has been found advisable to place the trunnions to the rear of the center of gravity of the tipping parts and near to the breech end of the cradle. The large muzzle preponderance resulting from this construction is compensated by the use of a balancing gear, called an equilibrator, consisting of a spring or pneumatic device arranged to exert pressure between the top carriage, or trail, and the tipping parts.

As indicated above, it is necessary to consider the mass of the elevating parts in making a complete mathematical analysis of the jump characteristics of a given design. Thus the moment of inertia of these parts is calculated about the axis through the trunnions. When the trunnions are located at center of gravity of the cradle, including gun, etc., which formerly was the usual practice, an inspection of equation (1) will show that jump should be greater for a given gun than it would be if the same cradle had the trunnions in rear of the center of gravity, because the moment of inertia would be greater.

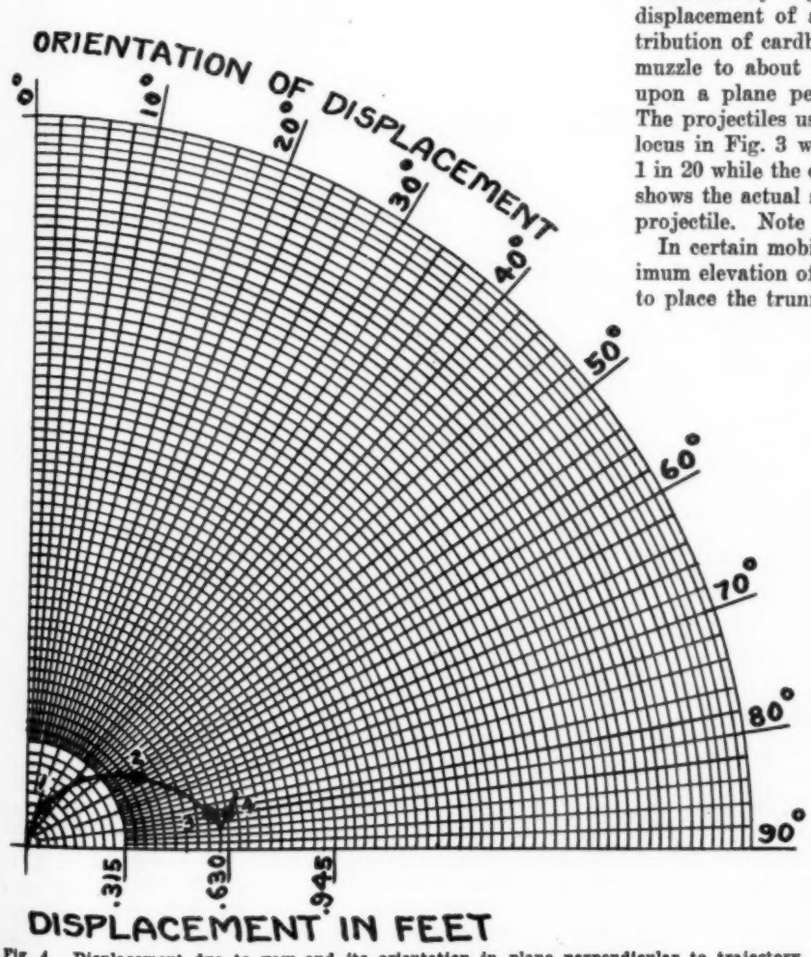


Fig. 4. Displacement due to yaw and its orientation in plane perpendicular to trajectory. Points indicate intervals of 100 feet; twist of gun, 1 in 15

The equilibrators have another effect that is worthy of consideration in analysis of jump. When too strong to just balance the elevating parts, the cradle will elevate until all backlash of gearing is taken up, so that the cradle would be restrained against positive jump by the gear teeth. When equilibrator is too weak the cradle will depress until the backlash is all taken up in that direction, but when the gun is fired the clearance would permit the cradle to jump in a positive direction. Hence it will be seen that in a carriage with equilibrator springs, the "jump error" will probably be less uniform than on a carriage where trunnions are at the center of gravity, because the preponderance of the equilibrator system is seldom found to be uniform between the limits of elevation, and furthermore there will be some variation of equilibrators between the several carriages in a battery, whereas the preponderance of a cradle trunnioned at the center of gravity does not change materially as elevation changes.

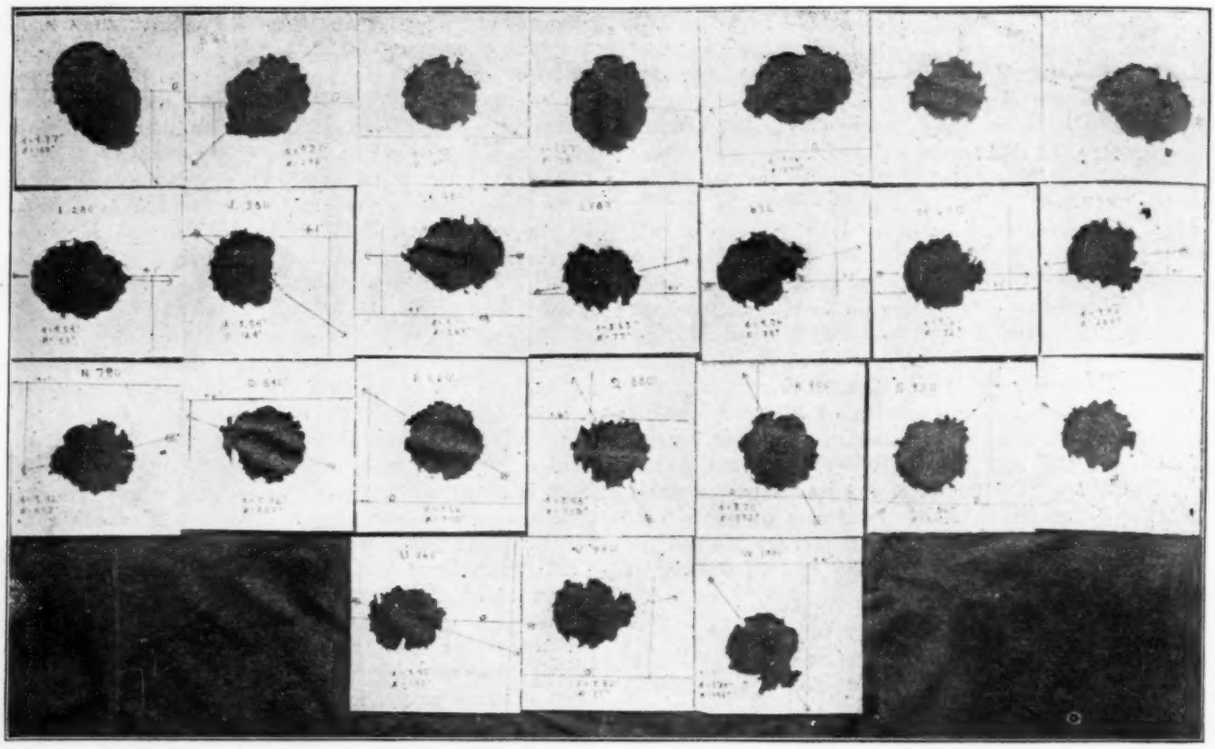


Fig. 5

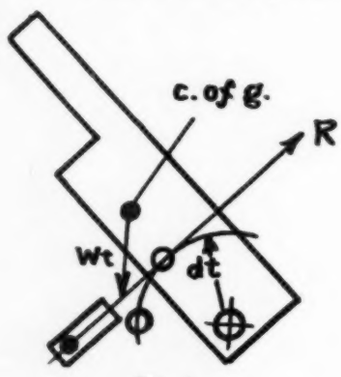


Fig. 6

In the case of carriages with axle traverse, where the cradle is trunnioned in the trail flasks, there should be only the slight variations in the amount of jump at different elevations referred to in the preceding paragraph, but with carriages having pintle traverse, the additional joints introduce other clearances to influence the magnitude and uniformity of the jump. Split trail types have some form of pintle traverse and some additional joints between the pintle and the parts that react on the ground. Readers who are familiar with the 75-mm. Gun Carriage, Model 1916, and the G. P. F. 155-mm. gun carriage types of split trail mounts, will readily see that the clearance in joints between the equalizer and trail hinge connections may also permit some angular motion of the piece in the former type, whereas in the latter type, there are no equalizer joints, and furthermore the large reaction at the rear ends of its trails will take up all clearances in trail hinge pins in the proper direction to eliminate motion that would tend to increase the magnitude of positive jump.

Influence of the Droop of Long Guns: Examination of "Jump Records" of various long guns on mobile and emplaced mounts reveals that the jump is negative in many cases where theoretical analysis of the mounting indicates that it would be positive. This may possibly be due to the influence of the droop, as the deflection of the chase due to its weight is called. The following theory may account for it, though the writers have not had opportunity to collect sufficient experimental data to corroborate it.

When bore-sighting on the "jump target" the line of sight from center of breech to center of muzzle is not the "quadrant angle of elevation" measured at the breech end of gun, nor is it tangent to the curved axis of the gun at the muzzle. Furthermore, it is rational to assume that the body of the gun does not completely straighten before the projectile leaves the muzzle and that the trajectory is therefore tangent to the deflected axis of the gun at the

muzzle. It would therefore pierce the target below the spot bore-sighted upon and when corrected for drop due to gravity, the net jump would be found to be negative, because the rotation of the axis of piece due to the action of the powder pressure is less than the angle CBD:

ABC is "line of bore sight,"
BD is tangent to deflected axis of gun,
BE is trajectory,
ED is drop due to gravity in time of flight from muzzle to target, E being the center of target perforation,
GAF is "quadrant elevation" if measured at the breech.

[Note.—The deflected chase might actually be deflected still further due to its inertia, as the gun starts to rotate.]

As to the effect on accuracy of firing, it is believed that the movement of the axis of the gun which causes jump is not as serious an obstacle to accurate firing as other movements of the carriage that are due to recoil of the piece, such as, recoil of the carriage along the ground, sinking of wheels and spades, and motion of the cradle due to backlash in the gearing and the joints of the carriage structure, because the jump is actually accounted for in the elevation given to the piece when the round is fired, while in some cases it is impracticable to relay the gun for each round, particularly in rapid fire and under such conditions the accumulative change in elevation due to movement of the carriage may have marked effect in varying the range and azimuth of a group of shots. In some matériel there is a tendency for the elevating mechanism to overhaul while the piece is recoiling, due to the sudden large increase in the breech preponderance as the piece recoils. Under certain conditions it may be conceived that the movement of the axis of the gun that is due to eccentricity of the center of gravity with reference to the center of the bore may greatly increase this tendency to overhaul. An example of such matériel is the 240-mm. howitzer carriage, Model 1918.

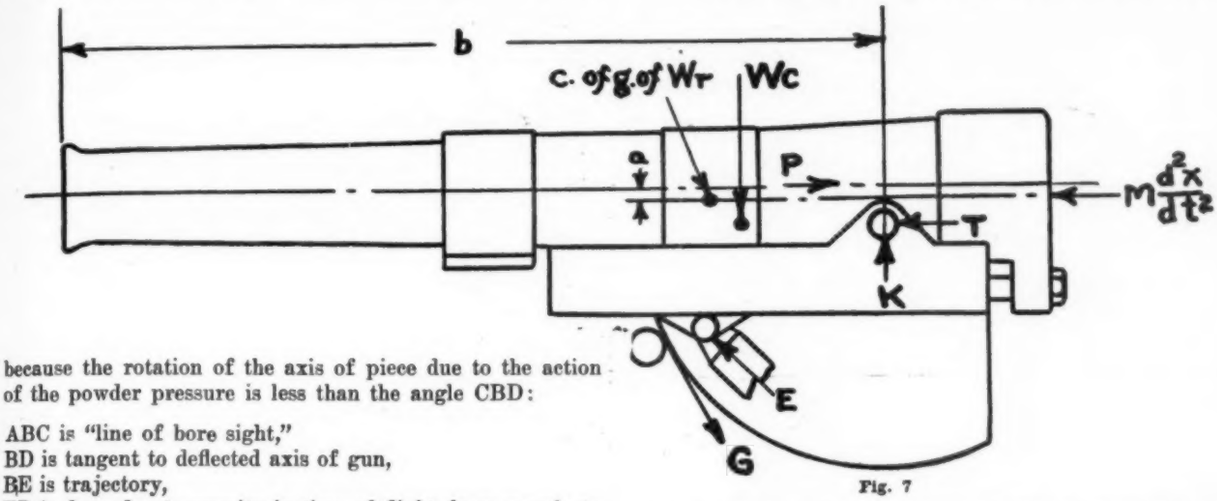


Fig. 7

It is for this reason that backlash in elevating and traversing mechanisms is deplored, rather than because it may permit greater angular movement of the piece, and thus increase the amount of jump. Since hop of a carriage on each round and settling of the spade will also cause disturbances of set-up, it is believed that the part of the actual jump of the projectile as it leaves the muzzle that is due to rotation of the parts of the carriage, has almost negligible effect on accuracy of fire, certainly much less effect than instability has.

75-mm. Gun, Model 1916 MIII, No. 722, on Carriage No. 1500, Carriage rounds No. 540 Up; Screen Distance, 44 feet. Shrapnel.

Rounds fired.	Angle of site mechanism.	Range elevating mechanism.	Jump-Minutes Maximum.	Minimum.	Average.
5	Depressed for each round	Elevated for each round	12.5	8	10
5	Depressed for each round	Depressed for each round	9	2	5.6 } 6.6
			12	7	7.5 }
5	Elevated for each round	Depressed for each round	10	7	8.6
5	Depressed for first round	Depressed for first round	12	3	8

75-mm. Gun, Model 1916, No. 71, Carriage No. 627, Carriage Rounds, No. 8280 Up; Screen, 44 feet. Shrapnel.

Rounds fired.	Angle of site mechanism.	Range elevating mechanism.	Jump-Minutes Maximum.	Minimum.	Average.
5	Depressed after each round	Depressed after each round*	17	12.5	15
5	Depressed after each round and bore-sighted	Depressed after each round and bore-sighted	9	2	5.6
5	Depressing first round	Depressing first round	28	7	

*Sighted with panoramic sight after first round.

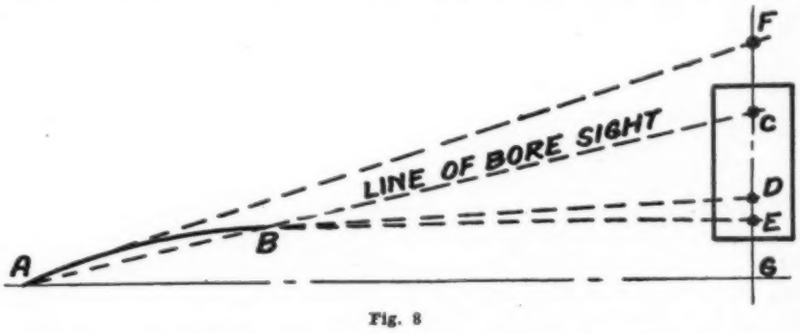


Fig. 8

The above is a tabulation of certain groups of rounds fired as indicated from a 75-mm. gun carriage, Model 1916, which is of the split-trail type. The rounds from gun No. 722 were fired after it had been in use for 540 rounds, while those from gun No. 71 were fired after it had been in use for 8,280 rounds.

Fig. 9 shows a typical cardboard target taken with gun No. 722 for the second series of five rounds listed in the above tabulation.

These data were determined in 1918 for the purpose of studying the effect of wear, etc., on the accuracy by firing through nearby vertical targets. In this model there are two elevating mechanisms, one giving range elevation to cradle while the other controls the rockers.

Therefore, the attempt was to see how the various conditions of contact of the worms with teeth in the racks, would affect the points of impact of the rounds on the vertical target. It will be noted in the latest firing tables that the jump of this model is given as 2.3 minutes for Mk. IV shell, and 1.5 minutes for shrapnel and Mk. I and Mk. II shell. The variation in the impacts on the target due to the manner of "setting up" given in the tabulation indicates that one could expect that the effect at an actual target at long range would be very significant when the gun crew was firing under exciting conditions and it would be natural for these variations to occur from round to round.

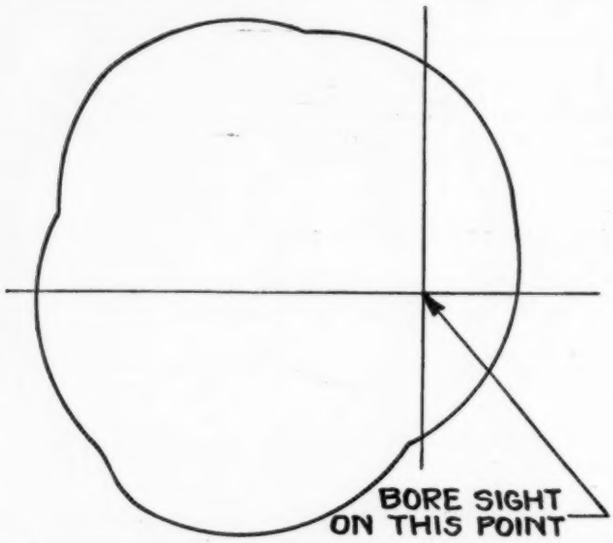


Fig. 9. Five rounds of shrapnel were fired for jump at target 44 feet from muzzle of gun. Gun bore-sighted on target and elevation and deflection noted. Elevation: 4 degrees, 6 minutes; deflection 1557 mils. Gun loaded and both angle of sight mechanism and range elevating mechanism depressed to position for each round for the five rounds fired.

Summary of Salient Points Concerning Jump

Jump should cause no inaccuracy during firing, if it is *uniform* for the several carriages, of a certain model, since the firing table elevations include the correction for it.

Jump should be determined for each kind of projectile at each velocity at which it is fired in a given gun since the yaw is different for various kinds of projectiles and for the same projectiles at different velocities. Furthermore, jump varies as the square of the time the projectile is in the bore, so the influence of muzzle velocity of jump is quite prominent.

If a gun is mounted on two or more types of carriages, the amount of jump should be examined by actual firings to see if there is sufficient variation to warrant the introduction of correction factors when using the same firing tables.

It is probable that jump is not influenced by an unstable carriage of conventional design.

It is regretted that sufficient data are not now available on which to base more positive statements in regard to jump. The effects due to instability of carriage and lost motion in elevating mechanisms have been fairly well covered. Those due to the use of equilibrators, the droop of long guns, the yaw of the projectile and the use of rubber-tired wheels can be measured and investigations to determine them are now in process, although due to limitation of funds and personnel progress is slow. It is felt that at best this article gives a survey of present available knowledge in regard to jump and points the way to a more complete analysis.

Activities of the New York Post

The fact that the New York Post had never had a formal charter from the Army Ordnance Association has now been corrected by receipt of a handsome charter now hanging, framed, in the office of its president. By this the New York Post, started in June, 1921, is recognized and established as "the New York Post of the A. O. A." Old members who did not belong to the A. O. A. may retain exactly their present status if they wish; or they may take either of the new "Joint-Memberships" now provided, the "Senior" at $7.00 per year for those who are willing to give that much aid to the "Industrial Preparedness" work of the Ordnance, or the "Junior" at $3.00 which covers membership in A. O. A. and New York Post, subscription to ARMY ORDNANCE, everything but voting rights. Both are welcomed to the fold, and their help—much or little—to further the cause of preparedness is a worthy service.

The dues simply pay postage, clerical help and other expenses and the journal, ARMY ORDNANCE, which is available as preserving interest and knowledge in ordnance technic.

The training camp at Camp Dix has about 25 officers of the Ordnance Section, Officers' Reserve Corps, and an interesting schedule has been laid out, including fundamental principles of ordnance engineering.

On July 20th the class was at Frankford Arsenal for a day's view of the processes of manufacture of small-arms ammunition and fire-control instruments.

Please write to Colonel Joyes, "The Ordnance Officer, Second Corps Area, Governors Island, N. Y.", if you would be interested in like visits this summer to Picatinny Arsenal, N. J., West Point or Watervliet Arsenal, N. Y., or to a seacoast fort near New York, as such can be arranged, but will not be unless there is interest in them.

Any other suggestions for get-together or instruction will be welcomed.

In the fall there will be a business meeting and election with some good attraction, later to be announced.

The Army Ordnance Association will hold its next annual meeting at Aberdeen Proving Ground, October 26, 1923. The American Iron & Steel Institute has been invited to attend. A fine program with novel features is expected, and there should be a record attendance.

Did you see the strong pronouncement in favor of "Industrial Preparedness" that the National Association of Manufacturers got out at their recent convention?

That is good *moral* support! But we need some personal actual demonstration of interest by members. What would you like to see done? What will *you do?* Do you read ARMY ORDNANCE? Would you like to get other reading matter, and if so, what?

Transport Wagons for Medium and Heavy Field Artillery

(German)

PART II

By

T. A. CONLON

THE Germans have made the most extensive use of transport wagons for their field artillery. Their use of this vehicle ranges over a wide caliber of guns and howitzers from the 100 millimeter to the 420 millimeter.

The wagons discussed here will illustrate a number of the varied types used by the Germans.

Medium Wagons

This vehicle (Fig. 1) is a Krupp design. They claim for it an advantage over wagons of its kind, in that it does not necessitate the lifting of the rear wheels of the wagon to bring it into proper position relative to the service

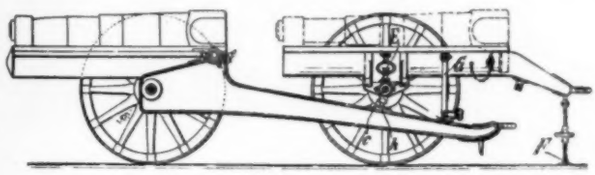


Fig. 1

mount, which arrangement requires the use of a powerful winch for raising the wagon when the gun is on it.

After the wagon is backed into position over the trail, the limber is disconnected and the wagon supported on the screw "F." Then the connection between the strut "G" and the eye on the axle is released. The carriage trail is then elevated until the ball "h" enters bearing "C" and is secured. The struts "G" are now to be connected with the trail. They serve as radius rods when connected with the axle. If the vehicle stands on uneven ground, it will be necessary to swing the body by turning the screw "E."

After establishing the connection between the wagon and

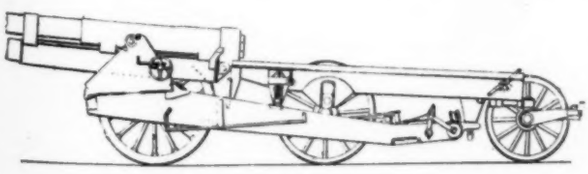


Fig. 2

the trail, the gun is unlocked from the cradle and retracted by pulley or other suitable means.

The maneuvering of a heavy vehicle of this type into proper position on uneven ground, as directed above, might require considerable time. There are no dead stops for the wagon, and it must come to rest in a position that will cause its longitudinal centerline to pass through the longitudinal centerline of the carriage, and the spherical seat on the trail to engage the sphere on the wagon when the trail is elevated.

The designer of this wagon (Fig. 2) also claims that it is not necessary to lift the rear wheels of the wagon to effect the transfer of the gun; however, provisions are made to lift the body of the wagon by jack screws on the rear end of the body. These screws rest on the trail when the wagon is in its loading position. The rear axle is free to slide in a vertical guide.

It will be noticed that the body is now a three-point suspension resting on the two screws in the rear and in the swivel socket on the limber.

In one design of this wagon the trails are lifted by handspikes, and in the other by a lifting winch on the wagon.

To facilitate ease of alignment when the wagon is backing into position, a traversing mechanism is employed to shift the body relative to the rear axle. Guide rollers on the rear end of the body engage the trail and ease the wagon into position.

With the wagon and service mount securely held together, the gun is pulled on or off the wagon with the assistance of

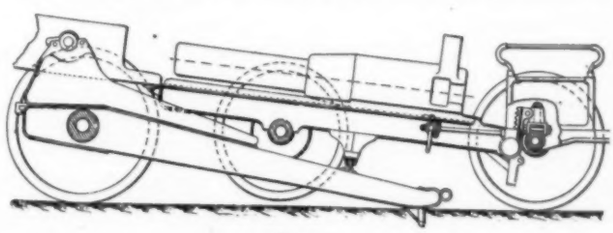


Fig. 3

a winch driving an endless chain. This chain passes over a sprocket at both ends of the body.

This transport wagon (Fig. 3) consists of a limber and a rear wagon connected together by an elevating mechanism, one part of which is universally jointed to the limber.

The apparatus is used as follows: The rear wagon is brought into position, the front end of the wagon being raised by the elevating mechanism to clear projections on the trail.

When the wagon is in position the body is lowered until the pivot and its seat are engaged. Then the body is lowered further until the rear wheels leave the ground and the slides come in line. The power required to raise the wheels is small, since the fulcrum is vertically below the center of gravity of the rear wagon and its load.

The vehicle is a three-point suspension.

This wagon (Fig. 4) is also of the slide track type, typical of the German transport wagons. One of the objects of this design is to render the wagon more secure against overturning during travel over uneven terrain.

To accomplish this the wagon is provided with a lifting mechanism that will permit of lowering the plane of the gun slides after the wagon is loaded.

The wagon consists of two side cheeks connected at the rear by the axle and at the front through the medium of a

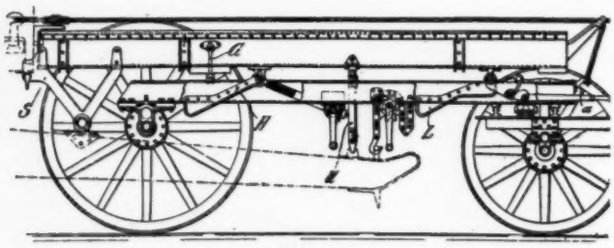


Fig. 4

pivot bearing with a king-bolt on the turning frame. To relieve the bearing pressure at the king-bolt, the truck is provided with a rail on which the carriage body rests. A winch is provided on the body to raise the gun trail. The chain of the hoisting device is carried over a sprocket, the hook on the free end of which engages an eye on the trail.

A gun support, the section of which corresponds to that of the slides on the service-carriage, serves to hold the gun during transport. Upon the upper edges of the side walls of the gun support s mounted a slde-track upon whch the gun can be drawn after the recoil brake has been disconnected.

In the transport carriage, according to this invention, the gun support can be brought into two different positions of elevation. In order to make it possible to raise this support from the traveling position to the receiving position and again lower it to the traveling position, the following arrangement is provided: Connected to the bottom of the support are two shafts M and N which project beyond the sides of the supports; on the ends of these shafts are antifriction rollers. The inner walls of the carriage body are provided with two pairs of guide rails H and L.

The gun support is elevated and depressed by the screw spindle shown under the wagon body. By turning the crank in the proper direction the screw spindle is retracted and the rollers made to climb the tracks on the wagon body.

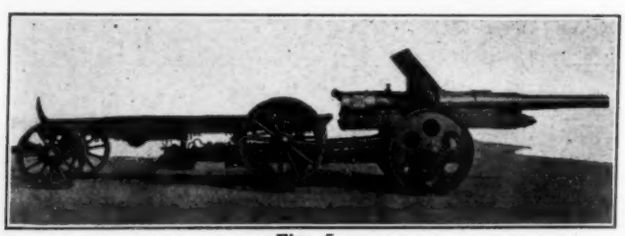


Fig. 5

The gun support is pivoted on the two shafts and has a limited movement relative to the wagon body. This movement allows the support to take the inclination of the service-carriage when the projections "U" and "S" engage the trails. The support is locked to the rear axle by the links "G" when on the road.

In order to effect the drawing back of the gun upon the wagon, a pulley carrier with two rope pulleys is provided. This carrier is hooked to the breech. The rope is passed around the pulleys, and one end is fastened to the hook "a" on the wagon; the other end is held by the gun crew and pulled in the direction shown.

To reverse this operation, the rope is fastened to the hook on the service carriage, and pulled in the opposite direction.

The wagon shown in Fig 5 is backed over the trail until the stops on the rear end of the wagon strike the ramps on the trail. Then the lifting chain engages the eye on the end of the trail, and the trail and rear end of the wagon are raised until the gun slides on the two vehicles are in the same plane. At this time the body is engaging the ramps on the end of the trail and half way up the trail.

The lifting mechanism consists of a worm and worm wheel connected to a sprocket over which passes the lifting chain.

The gun is retracted by a rope passing over rope pulleys on the breech, one end of the rope being held at the front end of the wagon.

The wagon is spring-supported in the rear, but not in the front. The front axles are connected to the wagon body by a fifth wheel.

The weight of the 130 millimeter gun is 7,400 pounds.

Unlike the other German transport wagons referred to here the wagon shown in Fig. 6 is loaded through the front end which is brought into contact with the muzzle end of the cradle.

The wagons are brought into line with each other, and the tractor removed. Then the winch cable on the side of the wagon is connected to the service carriage, and the vehicles

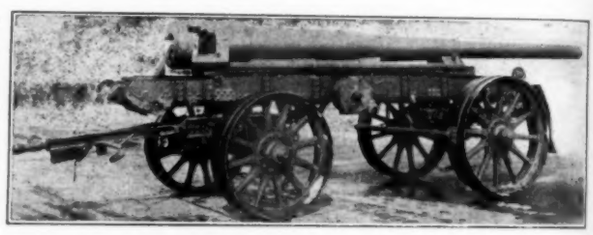


Fig. 6

drawn together. The wagon is guided by handspikes inserted into seats provided for them on the wagon limber.

When the wagon is in position, the hooks shown on the front end of the body are drawn into position by the lever, and are locked by the half-round pins in the lock.

The lever and hooks are keyed to the same shaft. The wagon is provided with a traversing mechanism over the rear axles and a rocking seat over the limber, which will assist in aligning the gun slides.

With the wagon in position, the gun and cradle, which move as a unit, can be removed from the service carriage by running the cable from the winch around the pulley on the rear end of the wagon body, and lock to the hook on the gun.

To unload the wagon, the cable is run from the winch over the pulley on the service carriage and locked to the hook on the gun. Rollers are provided in the carriage and wagon to facilitate the movement of the load. The wagon has a fifth wheel, is spring supported, is horse or tractor drawn, and has a seat on the rear for the gunner, who applies the road brake.

To load the 150 millimeter Gun Transport Wagon (German) shown in Fig. 7, the guide rails are put in place on the trail and the wagon backed over the trail until the guide rollers on the rear end of the wagon engage the rails. Then the wagon is run into its position, the rear wheels clearing the ground. The wagon is locked to the service carriage cradle. The lifting screws are let down to rest on the end of the trail. The limber is unlocked, and the front

end of the wagon elevated to bring the slides on the wagon in line with the slides on the carriage.

To haul the gun back, the cable on the winch drum shown on the side of the wagon is led over the pulley on the cradle and back over the pulley on the front end of the wagon, and then to an eye on the breech.

The wagon is spring supported over the front and rear axle. The brake is applied by an operator seated on the side of the wagon in front of the rear axle. The steering is done by a fifth wheel.

305-mm. Howitzer Carriage Wagon

The order which the vehicles take in marching and in which they are required on going into action is:

The procedure for erecting the howitzer is as follows: A cross-shaped excavation having been prepared to receive the platform, the lifting device is unloaded from wagon No. 1 and erected on rails in a very simple manner. By means of the lifting device, the platform is then unloaded from wagon No. 1 and assembled in the excavation, after which the outrigger is unloaded from wagon No. 2 and connected to the platform.

With the aid of rails attached to the outrigger, the carriage wagon (No. 3) is brought into position over the emplacement and the carriage set down on the platform. The cradle is then unloaded from wagon No. 4 by means of the lifting device and mounted on the carriage.

To assemble the two parts of the howitzer, wagons Nos. 5 and 6 (while standing on a level road) are connected by rails, the breech is then transferred to wagon No. 6 and connected up with the tube. Wagon No. 6 is then brought into position over the emplacement by means of the inclined rails, and the assembled howitzer transferred to the carriage. The latter operations necessitate the employment of a rope winch carried on the tractor by which the howitzer is manipulated.

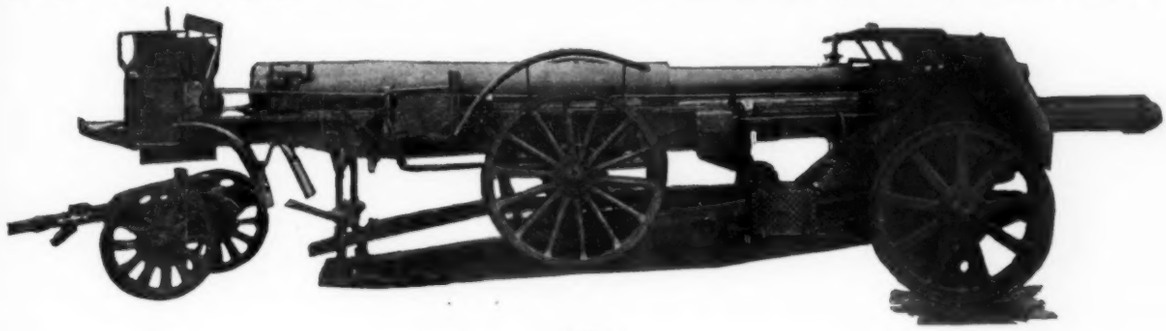


Fig. 7.

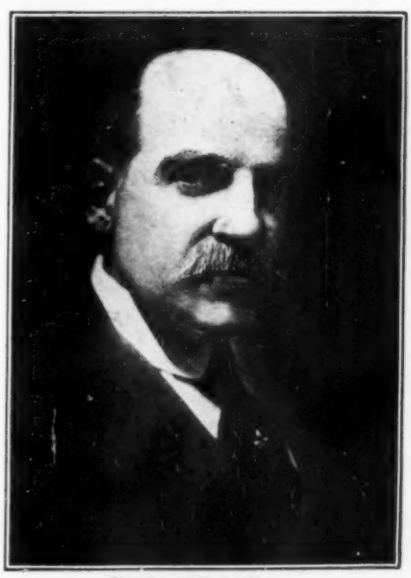
No. 1. Platform wagon I carrying lifting devices and cross-shaped platform.
No. 2. Platform wagon II carrying outrigger and pivot.
No. 3. Carriage wagon carrying carriage.
No. 4. Cradle wagon carrying cradle and small stores.
No. 5. Howitzer wagon carrying the breech piece (1,500 pounds).
No. 6. Howitzer wagon carrying the tube.

Colonel Warren to Command Antiaircraft Regiment

Members of the Army Ordnance Association will be pleased to learn of the recent appointment of Col. Charles Elliot Warren, Officers' Reserve Corps, to command the 502d Antiaircraft Regiment of the 12th Army.

Col. Warren has served as treasurer of the Army Ordnance Association since its organization, and his deep interest in the affairs of the association is second only to his co-operation with all matters of civic and national concern. He is vice president of the Irving Bank-Columbia Trust Co., of New York.

Col. Warren has had a most active military career. He served with the 7th Regiment, New York National Guard, and as regimnetal adjutant of the 12th Regiment. During the Spanish-American War, Col. Warren served as ordnance officer, inspector, and later adjutant general of the 5th Brigade, New York National Guard, with the rank of major. He was among the first to sponsor the "Plattsburgh idea," and was a member of the first Plattsburgh Civilian Training Regiment.



Charles Elliot Warren

Durnig the World War he served in the Small Arms Division of the Ordnance Office, later in the Procurement Division, on the staff of General McRoberts, and as a member and vice-governor of the War Credits Board, on the staff of the Secretary of War, Newton D. Baker. In addition to his office as treasurer of the Army Ordnance Association, Colonel Warren holds executive positions in a number of national societies, including director and treasurer of the American Officers of the World War, a member of the Military Order of Foreign Wars, and of the Society of the Cincinnati. Colonel Warren is a past president of the American Bankers' Association. He was most enthusiastic for the formation of the Army Ordnance Association and his interest has not diminished He was among the first to be commissioned in the Officers' Reserve Corps.

In his new assignment the Army Ordnance Association extends to Colonel Warren best wishes for the success that befits his active and distinguished career.

Automotive Testing

By

LEVIN H. CAMPBELL, Jr.

THE Automotive Testing Division at the Aberdeen Proving Ground was created to assist in the development of automotive matériel supplied the using services by the Ordnance Department. The recent war demonstrated the necessity of using in many cases, motorized artillery and special vehicles such as the tank. All new experimental automotive equipment is sent to the Proving Ground for an exhaustive test to determine weaknesses and to indicate in what way improvement may be made in design or material.

It is of interest at this point to outline the development history of any particular automotive vehicle. The Line of the Army indicates its need of a certain type of equipment and in general gives specifications therefor. The detailed specifications and studies are prepared in the Technical Staff and the Manufacturing Service of the Ordnance Office. The design and manufacture is then undertaken at Rock Island Arsenal and the completed vehicle shipped to the Proving Ground for test. Upon its receipt an officer of the Automotive Testing Division is assigned to the test, and insofar as possible, he is kept with the vehicle until the test is completed. His first duty is to thoroughly familiarize himself with the vehicle by a study of the detailed drawings and by actual inspection. A short run is then made to check the adjustments and to train the drivers in operation, care and maintenance.

A test program which is drawn up with a view to covering all possible uses of the vehicle in service is sent to the Proving Ground from the Ordnance Office, to be followed as a guide in the test.

At the end of each day's run the officer in charge of the test and the driver make a detailed examination to detect any failures or indications of weakness. A log sheet is then written by the officer, giving in detail all the happenings of the day's run, which includes all failures, unusual events, mileage run, average speed, grades encountered, oil and gas consumption, and such other information as will enable those who read the report to visualize the conditions under which the run was made. In all cases of failure or breakage of parts the officer indicates, first, that the failure occurred; second, the cause thereof; and third, the suggested remedy to insure against further failure of the part. In all cases of damage or breakage of a part a photograph is taken, so that the nature of the damage may be seen.

Aberdeen Tractor, Model 1922, under test

At regular intervals throughout the test, usually after 200 miles of running, a progress report is submitted in which the events of the log sheets are elaborated upon, all photographs are appended, and the recommendations and conclusions of the Proof Officer made.

By following this procedure a very accurate and complete history of test is available, so that an accurate comparison can be made between all vehicles which have undergone test. Six standard test routes have been laid out which afford varying conditions of soil and terrain.

In all test work it is constantly borne in mind at the Proving Ground that the vehicles under test are intended for service usage in time of war and therefore no attempt is made to "baby" the vehicle. The whole aim is to determine the suitability of the vehicle as a type and to detect, and if possible, correct any failures due to poor design or faulty material. On the other hand, the machines are invariably operated under the correct conditions as to lubrication, loads and speeds.

Of course, it is far easier to see where improvements may be made when one has the actual vehicle at hand than is the case when only drawings are available. For this reason one of the primary functions of the Automotive Testing Division at Aberdeen is to submit recommenda-

tions for improvements and corrections in existing designs, and also to make alterations to machines which are under test. As an instance, the case of the 2½-ton tractor, Model 1918, may be mentioned, in which the force at the Proving Ground removed the 8-cylinder Cadillac motor and substituted therefor the Liberty truck motor. This change, of course, involved other modifications incident to the installation of a larger and more powerful motor. Another case which may be mentioned is that of the water-proofing of the motor installed in the Mark VII Caterpillar Gun Mount for 75-millimeter gun. This motor was water-proofed at the Proving Ground, and subjected to a submergence test of more than two hours while running, during which it functioned perfectly. This was the first case on record of a gasoline motor having run submerged.

The test of automotive vehicles is in no way limited to those especially designed and built by the Ordnance Department. With a view to the large requirements for tractors in time of war, it is the constant endeavor of the Department to secure commercial tractors which will be suitable to military uses. To this end, from time to time various commercial tractors are bought and sent to the Proving Ground for test. A gun carriage of weight suitable to the drawbar pull of the commercial tractor is then towed over the same test routes as prescribed for all tractors and a careful record of performance is kept. In many cases these tractors have given excellent service, and their use in large numbers in the next war is undoubtedly indicated.

There is, however, a large field of development which must be carried on by the Department alone, as obviously no use exists commercially for such units as tanks, reconnaissance tractors, motor carriages for guns, special trailers and many other vehicles which are purely military in character.

A complete installation of an electric dynamometer for testing gasoline motors is on hand at the Proving Ground, and is of great use in determining the comparative efficiency of the various motors in use. For the determination of transmission and track losses in caterpillar tractors the Proving Ground is making use of the very fine tractor testing laboratory of Purdue University, and in this way we secure valuable data at a cost much less than the same information could be obtained. The University is now testing an Ordnance 5-ton tractor.

Campbell-Twamley Dynamometer

By

WILLIAM A. TWAMLEY

FOR some years the Ordnance Department has been experimenting with several types of traction dynamometers. While some features of each type have proven successful it has not been possible to find an instrument in which are embodied all the elements essential for the accurate determination of the data required.

Full view of Campbell-Twamley Traction Dynamometer

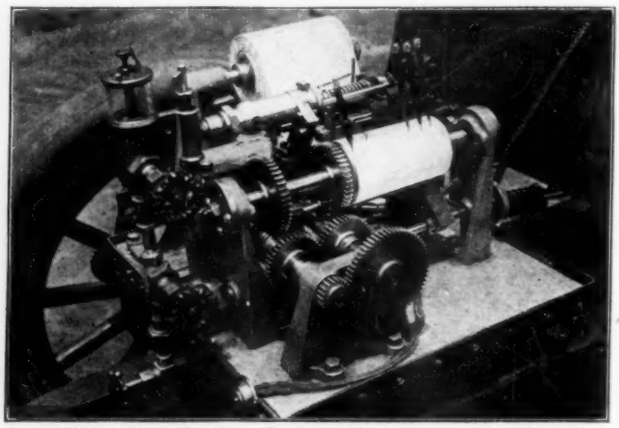
In the further development of existing types of automotive equipment and other kinds of mobile matériel, and in the design of new types in each of these classes, a very thorough and accurate knowledge of the various conditions of drawbar effort and tractive resistance is most essential, and to accomplish this successfully the instrument I will describe in this article has been developed.

The "Campbell-Twamley Dynamometer, Aberdeen Proving Ground, Model 1923," recently developed, is intended to overcome and entirely eliminate the objectionable features of the earlier types and to establish accurate data on such problems as the following: The drawbar effort of a given tractor or truck, the tractive resistance of a tractor or truck that has been disabled and that is being towed by another vehicle, the comparative tractive resistance of two gun carriages of identical design except that each carriage is equipped with tires of different cross section, or similar tests with various other types of matériel such as tanks, trailers, caissons and limbers. Many variations of the above data can be obtained by the use of different speeds and conditions of road surface such as concrete, dirt, cobble, gravel, mud, cross-country courses and gradients.

The dynamometer is a self-contained unit of the hydraulic cylinder type, in which oil is used as the medium, and comprises four principal parts: the chassis, the hydraulic cylinder, the measuring device and the recording instrument.

The chassis consists of a U-shaped, forged-steel axle, the ends of which are formed into square plates drilled near their vertical edges to receive bolts that carry the adjusting plates on which the wheels are mounted. The lower or central portion of the axle serves as the under side of a fifth wheel the upper part of which carries two semielliptic springs The springs carry the hydraulic cylinder and guides, the recording instrument and the operator. The wheels are of the standard Dodge type, and are mounted on the adjusting plates which are six inches wide and eighteen inches long and drilled near

their vertical edges, permitting an adjustment vertically of fifteen inches. This range of vertical adjustment will accommodate all conditions of pintle and lunette height for the different material being tested, allowing the axis of the piston and cylinder to be in a direct line between the drawbars of the towing and towed vehicles at all times. Tension springs are connected between the front end of the cylinder guides and the axle ends allowing the wheels to follow irregulaiities of the ground without affecting the alignment of the instrument. Screwed into the adjusting plates which are fastened to the axle ends are standard Dodge wheel spindles. Bolted to the inner side of the left wheel is a large gear-meshing with a pinion, mounted on a bracket fastened to the left adjusting plate, attached to the flexible driving shaft of the recording instrument. Two sizes of pinions are used for this purpose so that ten feet and twenty feet respectively will be represented by one inch of paper travel on the recording instrument. The large gear bolted to the left wheel also actuates a standard Dodge speedometer so connected by a flexible shaft and a suitable system of gears that a ratio of four to one is obtained at the speedometer. This was made necessary in order to obtain accurate readings at low speeds.



Campbell-Twamley Traction Dynamometer showing the Recording Instrument

The hydraulic cylinder is rigidly mounted in a yoke built up of heavy channel irons reinforced by forged steel transoms. On the top side of the upper channel iron the recording instrument is mounted. The piston, which is of steel and has an area of fifty square inches, is similarly mounted in a yoke built up of heavy channel iron. The piston is secured at its rear end to the reinforcing transom of the yoke. At the rear end of the piston yoke a standard pintle is mounted and at the front end a standard lunette.

The measuring instrument (manufactured by the Burr Machine Co., Champaign, Illinois), is a geared device mounted on an aluminum base and enclosed in a dust-proof hood. The gearing is so arranged that it actuates three drums, the first of which carries the record paper, the second moves the paper by friction, also serving as a foundation for the several recording pencils, and the third receives the completed record. The instrument is so geared and connected to the spiral driving shaft that twenty feet of road travel moves the paper forward one inch. By substituting another pinion this ratio can be increased to one inch of paper travel for every ten feet of road travel. An automatic reversing gear permits the paper to continue in the same direction when the direction of the dynamometer is reversed. It will not be necessary to describe in detail the other refinements of the measuring instrument.

The recording feature of the measuring instrument consists of a standard Tabor indicator, outside spring type. The indicator piston is one quarter of a square inch in area. A small pipe line connects the top of the hydraulic cylinder to the Tabor indicator. The pipe line is fitted with two valves. One is of the gate type and withholds the initial pressures, incident to starting a load, from the indicator, until the pull becomes steady, when it is opened. The other is a needle valve used to dampen the oil flow and reduce excessive oscillation of the indicator stylus. A third valve outside the system, but connected to the pipe line, is used in filling the cylinder. A gauge which indicates the pressure in the oil line is mounted on the dashboard. A completed record consists of five markings or lines, viz, the base line, pressure curve, traction recorder, time element and the observer's record. The base line is at the left of the record and is marked by a pencil fixed rigidly to the instrument. Before starting a record the indicator stylus is made to coincide with this line. The traction recorder is a pencil electrically operated and indicates every revolution of the driving wheel of the vehicle being tested and indicates, by comparison with the paper travel, the point where loss of traction begins. The time element is recorded by an electrically operated pencil, the time interval being obtained by means of a small spring-actuated motor mounted on the dashboard at the front of the chassis and governed to sixty revolutions a minute, which causes the pencil to describe a jog in the line at one-second intervals. The fourth pencil is electrically operated and is controlled by the observer for his convenience in recording different characters of road, speeds, delays, etc. The instrument was originally equipped with an automatic integrator which has since been removed as it was never satisfactory. The record is integrated manually.

The overall dimensions of the unit are length, eighty-seven inches, width fifty-nine inches and height forty-nine inches. Completely equipped, less the operator, it weighs 1,125 pounds. A spring seat for the observer is fastened to the reinforcing transom of the cylinder yoke.

This instrument, in conjunction with the Sprague Electric Dynamometer at the Aberdeen Proving Ground and the Absorption Dynamometer which has been designed, will enable the Ordnance Department to collect data of a character it has been seeking for years, and will assist materially in the development of automotive vehicles.

Testing Small Arms and Ammunition

PART II

By

GLENN P. WILHELM

Erosion Test (Continued)

The machine-gun test is fired at 1,000 inches because it is impossible to maintain a rate of fire corresponding to the rate sometimes encountered under service conditions in barrage work and keep the groups on a target at a greater range. This distance is also chosen because the bullet is more unstable close to the muzzle than it is at any other range and any inaccuracy that affects the stability of the bullet, such as wear in front of the chamber causing the bullet to be slightly deformed, shows up at that distance. For purposes of checking, tests have been fired through the roller screen at 1,000 inches onto a water area at 2,000 yards, and a comparison being obtained on the same bullets at both ranges. The results checked fairly closely.

Another reason the test is fired with the machine gun by automatic bursts is because it has been found impossible to determine the barrel life by means of single shots when the barrel is cold and measuring the mean radius of the shot group. In other words, this test takes into consideration that there is no analogy between the rifle and machine gun barrel in so far as the effect of erosion on dispersion is concerned, due to the different tactical uses and the consequent degree of heat involved, as well as the difference in precision between the two weapons.

In the rifle, the erosion test is fired somewhat differently. The rifle is fired at a rate of fire of one shot every 5 seconds, with a one-minute interval between every shot group of ten shots each. At the end of every 100 rounds the barrel is cooled by means of water, but is not cleaned, other than swabbing out the water. At the beginning of the test, which is fired into a roller screen at 200 yards, the first ten-shot groups are measured for mean radius and the usual target measurements. Ten-shot groups for checking purposes are also fired at 600 and 1,000 yards. Thereafter, shot groups are only taken at 200 yards, the first five-shot groups of ten shots each in every 500 rounds being recorded only, the remaining shots not being recorded.

Before the test is begun, velocities, pressures and star-gauge measurements are taken. Thereafter, these measurements are repeated periodically, depending upon the nature of the test; for instance, after every 1,000 or 2,000 rounds, and also at the end of the test. The barrel is considered as worn out after the average mean radius of any five-shot groups exceeds by 60 per cent the original average mean radius for the first ten shots.

Time of Flight.—Measurements for time of flight of small-arms bullets at the longer ranges at the present time are determined approximately by the use of observers using stop watches graduated to one one-hundredth of a second; the observer, who is located in a tower at the water impact area, getting the sound of discharge of the gun over the telephone and observing the splash of the bullet in the water. For times of flight over one or two seconds, providing a sufficient number of observations are taken, this method is fairly reliable. Of course, at the shorter ranges the time of flight is obtained by means of the chronograph.

Angle of Fall.—It has been found that the best way to obtain the angle of fall is by computation from the other elements of the trajectory. It can be measured, however, by means of the paper screens, which have the big disadvantage that at the longer ranges they must be fairly large and strong enough to resist the wind and they therefore have been found to affect the flight of the bullet, and large errors result.

Determination of the Trajectory.—Experience has also shown that the trajectory can be best obtained by computation from the other elements of the trajectory which can be readily and accurately measured, such as the elevation and the time of flight. However, up to ranges of about 1,200 yards, the actual trajectory can be measured by firing through paper screens and thus recording the flight of each bullet at the intermediate ranges. This method is subject to the same disadvantages as the time of flight measurement, inasmuch as the screens often affect the flight of the bullet.

Testing of Light Armor Plate.—On account of the importance of thin armor for tanks, gun shields, airplanes, and wherever protection against small arms is deemed necessary, it has been found advisable to run comprehensive tests on light armor plate. The method of making the test has been standardized by the cooperation of the Ordnance Department and the Navy Bureau of Ordnance.

The primary object of the test is to determine the actual striking velocity necessary to penetrate plate with standard armor-piercing ammunition under certain conditions. The size of the plates is usually one foot square, the plates being supported on a standard butt that firmly and rigidly holds the plate. All impacts are normal, the ammunition being fired from a standard rifle in a machine rest. The velocity of each shot fired is taken and the velocities are gradually increased until penetrations are obtained.

A considerable amount of data is recorded, including photographs of the plate and the various characteristics of impact, such as fracture, penetration, cracks, etc. For this work the Aberdeen chronograph is particularly valuable, inasmuch as a large number of shots can be fired through the leadfoil screens onto the armor plate without repairing the screens. The Boulengé chronograph is not very suitable for this work, as ordinarily the circuit is broken by means of a disjunctor at the second point of contact. Since in this case it is necessary to have the bullet strike the armor plate, this cannot be done and it would be necessary to make a set of special wire screens which would have to be mended at every shot.

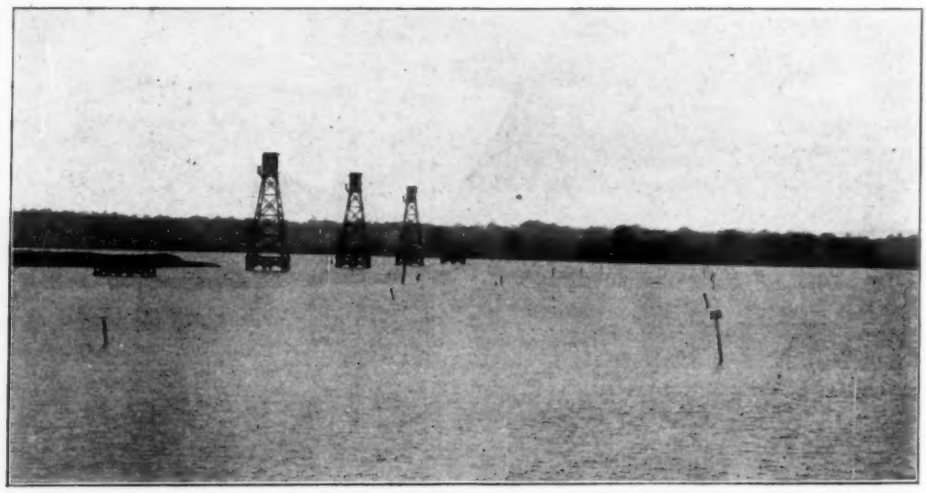
In connection with the stability of the bullet, it was found that, if the distance to the plate were too close, the bullet shattered on impact, as it appeared to be wobbling. This is of particular interest, in view of the lack of stability of the bullet at 1,000 inches, as previously remarked in the case of the erosion test with the machine gun.

Miscellaneous Tests.—A great many other tests are car-

ried on at the small arms range; such as rifle cleaning solutions, machine-gun tripods, anti-aircraft tripods, various types of special ammunition, such as tracer ammunition, and any other firing which must be carried on in connection with the development of small arms and ammunition.

Future Methods and New Installations.—At the same time that routine tests have been carried on at the range, as above described, studies and development work have been carried on with the idea in view of so improving the range as to increase the speed of carrying on tests and yet, at the same time, to obtain more reliable data at a decreased cost and with a less number of men. This work is of particular interest, inasmuch as little or no improvements have been made in connection with the testing of small arms in the past twenty or thirty years, except the adoption by the Ordnance Department and the ammunition companies of the use jected on a plotting board and one observer makes a permanent record on a piece of white paper of the splash made by each bullet as its image appears. In firing machine-gun bursts, it will be necessary to use about three observers who will mark the outer limits of the dispersion by means of the projected image.

The Machine Gun Microphone Installation.—While it is possible to determine the exact location of each shot in the machine-gun burst by means of motion pictures, yet this is an expensive and more or less complicated method. For the purpose of determining precisely the pattern of a machine-gun burst on the water impact area, also for the determination of the time of flight of bullets at long range, and particularly the time of flight of each machine-gun bullet in a burst, there is also being installed apparatus which will enable all of these data to be permanently recorded independently of any personal error. This de-



Water Impact Area, Small Arms Ballistic Range at Aberdeen Proving Ground

of the Mann rest. The present method of obtaining pressures and velocities has been in use for a great many years.

One of the biggest difficulties in carrying out the tests at the present time is that a different set of shots is used when firing for pressures than is used when determining velocities, and the same thing is true of the elevations and the dispersions. In making a study of future improvements, therefore, it has been with the object in view of obtaining, if possible, a method which will allow the simultaneous determination of all the above factors.

Roller Targets.—The speed of determining the accuracy of a given type of ammunition in both rifle and machine gun by means of shot groups, both in accuracy tests and erosion tests has been greatly increased by the use of roller screens, which has been brought about very recently. These consist of rolls of paper, as hereinbefore described, instead of the usual targets. In future, it is proposed to use roller screens for all firings at 200 and 600 yards and possibly even at 1,000 yards.

Use of the Camera Obscura on the Water Impact Area.—The method of determining the location of the bullet splash on the surface of the water impact area at the present time involves the use of observers in towers who estimate the location of the splash with reference to stakes set out in the water. This method is somewhat inaccurate, requires at least three observers and does not make a permanent record. On the central tower it is planned to install a camera obscura, so that an image of the surface of the water is pro-

velopment work is being successfully completed by Dr. E. A. Eckhardt, physicist, of the Bureau of Standards, who undertook this work at the request of the Ordnance Department.

The principle on which the apparatus is based is briefly as follows: A microphone is placed near the muzzle of the gun and another microphone at about 100 feet from the muzzle. Six microphones are also placed in the water impact area. The impact of a bullet in the pond terminates the time of flight and the six microphones in the water respond to the splash sound. If the transmission of sound in the water were instantaneous, all six microphones would record simultaneously, but the speed of sound in water is approximately 1.57 yards per one one-thousandth of a second. All of the microphones are connected by telephone lines to a central station, where the impulse is registered by means of a suitable recording mechanism on a moving tape or film. Time index marks by means of a vibrating tuning fork are also registered on this same film at 1/500 second intervals. By varying the speed of the film, the time index marks can be sufficiently separated so that the film can be read to .001 of a second. Thus time of flight can be determined approximately by inspection of the record, as the number of index marks from the record of the first microphone at the muzzle to the index marks from the microphones in the water will give this to within an error of about 6/100 of a second.

The accurate determination of the time of flight is done

graphically by reading from the record the time intervals between the responses of at least three microphones, similar to artillery sound-ranging methods. If the time intervals are measured to the nearest .001 of a second, the points of impact may be determined to the nearest two or three yards, and possibly better. Therefore, to determine the precise time of flight, it is necessary to locate the point of impact, and this is one of the very valuable features of this apparatus, as this will do away with the observers, or even the use of the camera obscura. The procedure followed in determining one point of impact may be used for determining all the points of impact of every shot in the burst, so long as the rate of fire does not greatly exceed 600 shots a minute. This entire system, when used in connection with machine-gun bursts, is based upon the fact that the time interval between firing successive shots is greater than the extreme variation of the time of flight.

Of course, the muzzle velocity is obtained by the two microphones placed in front of the gun. Such data is considered important in connection with every shot in the machine-gun burst, particularly in view of the location of each shot, as some relation may be found between the arrangement of the pattern and the muzzle velocity.

The apparatus necessary to obtain the above makes its record photographically and this is the biggest disadvantage, because it involves a delay between the time the shots are fired and the obtaining the record. In some tests it will be necessary to use either the observers, as is done at the present time, or the camera obscura, as the range obtained with a given elevation often determines the need of additional firings.

Combination Aberdeen Chronograph and Microphone Recorder.—At the request of the Ordnance Department, the Bureau of Standards is installing another type of apparatus, which will be used at the shorter ranges, i. e., not greater than about 1,000 yards. This development consists of a vacuum tube relay device which, together with coil screens and an Aberdeen chronograph recorder, aims to provide means for the velocity measurement of bullets, which avoids the necessity of photography, with its consequent delay in noting the result, and which gives the velocity of bullets without the use of any kind of screen that might either affect the flight of the bullet or which must be repaired.

The preliminary experiments were carried out by means of Joly interrupters. These interrupters were placed at intervals along the flight of the bullet and were operated by the bow wave of the bullet. Of course, if the velocity of the bullet is below that of sound, there is no bow wave. For this reason the apparatus cannot be used at the longer ranges. Care, of course, must be taken that the bullet passes the interrupter at a distance small enough so as not to affect the accuracy of velocity determination.

The value of this apparatus can be instantly perceived. For instance, in firing at a range of 600 yards, not only can the muzzle velocity be determined by means of the interrupters, but the time at which the bullet passes any intermediate point can also be determined. If a shot group of ten shots is being fired, the velocity and retardation of each bullet in the shot group can be determined simultaneously with the obtaining of the group itself.

In order to insure that the bullet passes sufficiently near the interrupter, it is necessary to adopt one of the following methods. The first method is by means of armor plates so located that the bullet will strike the plate at each interrupter unless it is within a given distance of the interrupter. The second method is by firing through the usual paper screens and discarding all shots that do not come within a certain distance of the interrupter. In this connection, the interrupters can be operated directly by impact of the bullet on the paper screen, thus doing away with the error of the bow wave.

The use of this apparatus will permit the simultaneous determination of a large amount of data. For instance, by fitting the device which is used to obtain pressures to a Mann barrel and firing a group of ten shots from the Mann rest, all of the following measurements may be taken on this group:

Accuracy.
Elevation.
Trajectory.
Muzzle Velocity.
Pressure.
Time of Flight.
Retardation of bullet over equal intervals of either time or distance.

The latter phase, that is, the retardation of the bullet, will be particularly facilitated by the use of the Aberdeen chronograph in connection with the interrupters. For instance, at the present time the only way that retardation of small-arms bullets can be measured is by taking successive measurements over several distances with different bullets, using either the Boulengé screens or the Aberdeen screens, the Aberdeen for this purpose being considerably superior to the Boulengé. Neither method, however, will enable the same intervals to be determined over successive intervals for the same bullet without affecting the flight of the bullet by passage through the screens and then it is necessary to go to considerable trouble in the use of screens and instruments.

The Piezo Electric Gauge and Its Application to Small-Arms Pressures.—The Bureau of Standards is also experimenting with an apparatus for determining the pressure in large caliber guns by means of the Piezo electric gauge. The design of this gauge is based on the fact that a quartz crystal, when suddenly compressed in the direction of the electric axis, will actually generate a minute electric charge which is proportional to the pressure to which the crystal is subjected. By means of a plunger operated by the pressure to which the gases expand upon firing, the electric capacity of the quartz crystal, before the pressure occurs and afterwards, is determined by means of a galvanometer and a photographic film. An application of this gauge is planned for small-arms pressures in the following way.

At the present time comparative pressures are obtained in small arms by means of copper pressure cylinders that are compressed by the movement of a plunger when the piece is fired, the measurements being taken before and after. Considerable variation is obtained in the pressures taken with these copper cylinders, depending upon a large number of factors, such as whether the coppers are previously compressed or uncompressed and upon the similarity of the coppers to each other. Tarage tables have been prepared by which a comparison is made between coppers which have been precompressed for certain amounts and coppers uncompressed. The table itself is unsatisfactory and great difficulty is encountered doing test work from time to time with various makes of ammunition on this question of pressures, as it is known that not only are the actual pressures not obtained by means of the coppers, but even a true comparison is not always obtained. It is, therefore, proposed to make up a pressure gun that will allow three pressures to be determined simultaneously; one pressure being with the uncompressed coppers, one with the precompressed coppers and one with the Piezo electric gauge. By this means a comparison of the three would be possible and new tarage tables, based upon the actual pressures as shown by the elec-

tric gauge would be made, so that not merely would a better comparison be obtained, but the final results would be nearer the actual pressures obtained.

Conclusion.—It is impossible to foresee the effect that the foregoing improvements will have upon future development and design of small arms and small arms ammunition. If it is practicable to determine simultaneously all the elements of the trajectory an advance will be made which will be so far ahead of anything that has been possible in the past that doubtless a number of the difficulties and factors that now affect any improvement in design will be eliminated. While it is necessary to be conservative in making any changes in the routine test of arms and ammunition, yet at the same time, great strides have been made in the past few years in laboratory experimental work and it is only by utilizing the best among the physicists and scientists of the various Government bureaus, such as the Bureau of Standards of the Department of Commerce, that the greatest progress can be realized.

It is rare that the gunsmith or the ordnance expert is at the same time a capable physicist. On the other hand, the laboratory expert is even more ignorant of the ballistic problems that confront the ordnance engineer. It is only by combining the specialized services of the scientist and the ballistician that there will be achieved an era in development that should eclipse even the brilliant record of the past.

Book Reviews

"Memorial De L'Artillerie Francaise," Paris, Imprimerie Nationale—Volume I, 1922, Vol. II, 1923, 115 francs each.

ARMY ORDNANCE takes pleasure in welcoming into the field a new military-technical publication. The *Memorial de L'Artillerie Francaise*, the first volume of which has recently been received, is characteristically French in the thoroughness with which the theory underlying the science of ordnance is developed. The fact that the chairman of the editorial board is General Charbonnier will be a sufficient guarantee of the high standard of the publication to the American public. Associated with General Charbonnier is a corps of eminent engineers representing the French Ministries of Marine, of War and of Public Instruction. French industry is also represented on the editorial board.

The *Memorial* was instituted by presidential decree dated July 23, 1921. Its object is to develop the technical side of artillery in a manner parallel to the development of the tactical use of artillery by the *Revue d'Artillerie*.

In his report to the Minister of Marine, General Charbonnier states: "The doctrine of the Naval Artillery has always been to give to its work the largest publicity and to submit it to free discussion by all.

"In thus diffusing its theories and its methods, in avoiding keeping them the jealously guarded property of a chosen few, it evidently runs the risk—perhaps in fact very small—of furnishing the enemy with arms which he may use. It considers, however, that the advantages of publishing these works outweigh the disadvantages."

The *Memorial* will carry original articles, translations from foreign publications and bibliographical notices. The original articles will cover such subjects as ballistics, theoretical and experimental; gun construction; theory of recoil brakes; powders and explosives; projectiles; fuzes; probability of fire; industrial mobilization; etc.

The numbers already issued testify to the high quality of the endeavor.

R. H. S.

Metals and Their Alloys, By Charles Vickers. Henry Carey Baird and Company, Inc. 110 Illustrations. Price, $7.50.

Mr. Vickers in the preface to his volume says that it is his aim to present "a thoroughly practical book filled with the formulas most widely used, the presentation being made in as simple a manner as possible, and thus as easily available for the unskilled man as for the technically trained worker." This objective the author has attained in a most convincing and scholarly manner—convincing in the scope and detail of the subject matter, and scholarly in the method and treatment of the topics.

The book contains 31 chapters of which the first four are given to a rather academic discussion of the properties, uses and production of the chemical elements, and the groups and characteristics of the alloys. Individual chapters are given to alloys of the various metals and it is in this respect that the work deserves the highest praise. Mr. Vickers leaves little of his subject without excellent treatment. We recommend the work most highly.

L. A. C.

L'Artillerie Nouvelle. By L. Thouvenin, Captain of Artillery. Charles Lavanzelle and Company. 316 pages, 300 illustrations. Price, 6 francs.

This is a very clear and concise work which undertakes to describe the various types of French ordnance matériel. The book contains three well-proportioned parts. The first treats of ammunition and components, including powder charges, projectiles and fuzes, and gives an excellent description of the design and function of the several types of each.

The second part discusses artillery fire with particular emphasis on methods of adjustment.

Part three considers the various developments and present types of French artillery matériel.

The book is interesting and should be a handy reference to those who follow and who are responsible for the design and manufacture of our own ordnance.

R. H. S.

Handbook of Ballistics, Volume I. By Dr. C. Cranz and Captain K. Becker. Translated from Second German Edition. His Majesty's Stationery Office, London. 483 pages. Price 30*s* 9*d*.

His Majesty's Stationery Office has performed a very valuable service in making available to the English-reading public this translation of Dr. Cranz' reliable text on exterior ballistics.

The topics treated include: the motion of a projectile in a vacuum; air resistance; solution of differential equations; high angle trajectory; construction of range tables; lateral deviations of shell; lateral deviation due to rotation; and the ballistics of penetration.

This is a work that needs no introduction to the tried and trained ballistician. We take this occasion to praise it because it is clear and authentic doctrine for the beginner and those who choose to browse along the paths of applied higher mathematics.

L. A. C.

Spring Return *versus* Recuperator

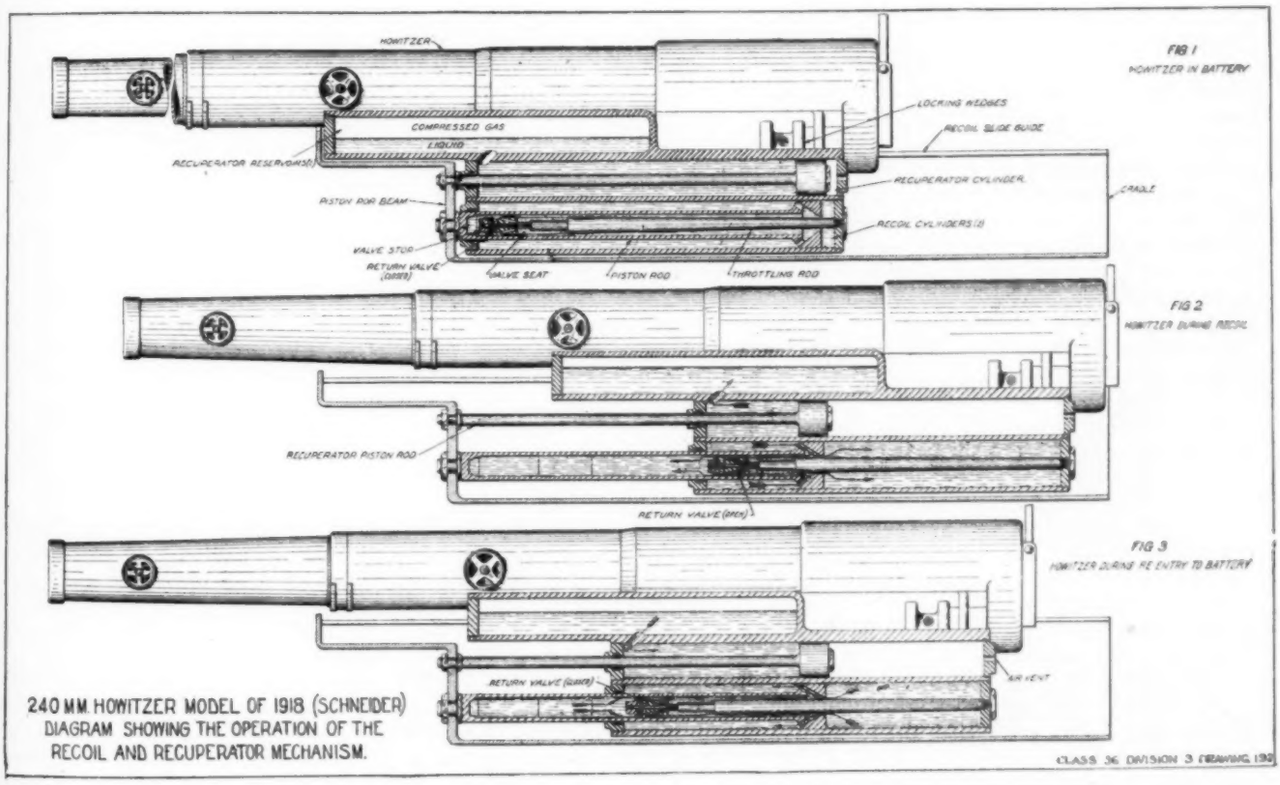
By

J. E. MUNROE

FOR many years field artillery carriages of the United States Army had incorporated in their design the principles of absorbing energy of recoil by hydraulic cylinders and of returning the gun from its position of extreme recoil to the firing position by means of helical springs assembled with considerable compression, which is increased by movement of the gun in recoil. These springs absorb a small part of the energy of recoil but their chief function is to return the gun to the firing position. They must be powerful enough to do this in a reasonably short time against the resistance of the recoil oil passing from one side of the piston-head to the other, the counter recoil buffer, and gravity, when the gun is laid in elevation.

Limitations on weight demanded by the using services resulted in designing recoil springs of very high fiber stress which caused considerable difficulty in manufacture. These springs were the source of dissatisfaction in the field, because after continued use many springs took a permanent set and there were numerous breakages of springs not only while in use, but even during storage. The objectionable features of the spring-return system were thus a matter of common knowledge, and the service in general welcomed the change to the hydro-pneumatic system, which came about through our adoption of French types.

We have now had several years' experience with recuperators and it is believed that the time is ripe for an analysis of the relative advantages and disadvantages of the hydro-spring and the hydro-pneumatic systems. The following advantages are claimed for the hydro-spring system:



240 MM HOWITZER MODEL OF 1918 (SCHNEIDER) DIAGRAM SHOWING THE OPERATION OF THE RECOIL AND RECUPERATOR MECHANISM.

CLASS 36, DIVISION 3 DRAWING 190

Simplicity of design and manufacture;
Lower initial cost;
Easier to reach maximum production in time of war;
No secrecy required;
Easier to understand principles of operation;
Easier to repair;
Lower cost of maintenance in storage;
Easier to control length of recoil and violence of counter recoil;
Fewer tools and accessories required;
Lower weight (for smaller calibers only).

The design of hydro-spring systems has been practically standardized. The calculations are comparatively simple

and there is practical assurance that such a system designed and manufactured for a pilot vehicle will function very nearly as intended. In case of failure to so function, a remedy is usually obvious. With hydro-pneumatic systems this condition does not obtain and it has been the experience at Rock Island Arsenal that considerable modification of pilot vehicles has been necessary to secure satisfactory operation. The hydro-spring type is much simpler than the hydro-pneumatic in the number of parts, variety of material used, manufacturing tolerances and degree of finish. These characteristics result in a marked difference in cost in favor of the hydro-spring type.

These characteristics also mean that the difficulty of attaining production sufficient to meet war-time requirements would be much less serious in the case of the hydro-spring type. It is probable that facilities already exist in this country which would be ample to produce all the springs required without seriously interfering with other essential spring manufacture. Fewer single purpose machines and fewer jigs and fixtures would be required for the manufacture of the hydro-spring type than for the hydro-pneumatic, thus increasing the ease with which a manufacturing plant could be adapted to the manufacture of recoil mechanisms in time of war.

Among the conditions imposed by the French Government in turning over to this country drawings of recuperators and information concerning their manufacture, test and operation, was a provision that certain drawings and processes be maintained secret. This provision has been a great hindrance to a thorough understanding of the recuperator mechanism by the using services. It has resulted in many complications during manufacture and has prevented understanding of the mechanism on the part of many employees who are actually engaged in the manufacture of parts of the mechanism. It is difficult for the individuals, whose duties require them to understand the complete recuperator mechanism, to bear in mind what particular drawings and processes are secret. The result is that secrecy is maintained on many parts concerning which there is no necessity therefor.

The principles of operation of the hydro-spring type are easily understood and there are few enlisted men in a battery who are not able to explain its action. With the recuperator, there are few enlisted men who can understand or explain the principles of operation. It is believed that even many Artillery officers have very hazy ideas of the details of the recuperator mechanisms. The dismantling of recuperators in the hands of troops is prohibited, not only on the grounds of maintaining secrecy, but also because special tools are required to disassemble and assemble properly and unless properly done it is probable that serious damage to the mechanism would result. The experience of the Rock Island Arsenal on repairing certain recuperator mechanisms which have been turned in from the field shows that this objection is well founded. The only adjustments which can be made in the field are variations in the amount of oil and of nitrogen. If these adjustments fail to correct any difficulty of operation, the recuperator must be sent in to a repair shop.

The hydro-spring type may be, and frequently has been, completely disassembled and reassembled in the hands of troops where replacement of defective springs and any other repair not involving machining operations can be readliy performed. It is difficult to ascertain how important this advantage might be in time of war, but it can readily be seen that such an advantage might easily compensate for any serious disadvantages the hydro-spring type might have.

With recuperators it is highly important that the friction of moving parts be kept nearly constant. With this end in view, sliding parts are given a very high polish, springs are carefully adjusted and much depends on packings operating uniformly. The packing materials from which best results have so far been obtained, viz., silver, rubber, leather, and dermatine, are unfortunately subject to deterioration from oxidation, as are also the highly polished steel surfaces. It is almost impossible to secure a recoil oil which will prevent oxidation of these parts, and in the case of rubber, leather and dermatine, the material undergoes chemical changes irrespective of the surrounding medium. This deterioration of rubber, leather, and dermatine makes the proper maintenance of these parts expensive whether they are stored separately or assembled in the recuperator. A slight film of rust, which is inconsequential in a hydro-spring type, is a serious matter on the highly finished parts of a recuperator. When such a surface becomes pitted with rust the only remedy is to refinish the part, thereby changing dimensions and requiring non-interchangeable parts.

The requirements for a recoil oil are practically the same for both types of mechanism except that in the case of oil for recuperators it is more important that acidity be kept very low in order to minimize rusting of steel surfaces. The presence of sediment, particularly of a gritty nature, is more serious with recuperators than with the hydro-spring type.

Most recent types of hydro-spring systems either have incorporated in their design, or could easily have, a recoil valve and a buffer valve whereby the length of recoil and the violence of counter recoil can be easily regulated. Such valves could be applied to the hydro-pneumatic type only by considerable complication of parts. Adjustment of recoil and counter recoil is highly desirable on account of the impracticability of procuring a recoil oil of constant viscosity with changing temperature. With some recuperators it is unsafe to fire in extremely cold weather without first warming the recoil oil.

The hydro-spring type requires no supply of nitrogen, no pressure gauge, no battery pump and only a few simple tools for complete disassembly. The hydro-pneumatic type requires a supply of nitrogen under high pressure, pressure gauges, a pump to replenish oil leakage and many complicated tools for complete disassembly.

The hydro-spring type for small calibers is considerably lighter than the hydro-pneumatic type. For the 6-inch gun and 8-inch howitzer and larger calibers, it is probable that the hydro-pneumatic type would be lighter. For larger calibers it is also probable that difficulty would be experienced in accomplishing the necessary compression of springs in the field.

In weighing the relative advantages and disadvantages of the two types, it is apparent that the hydro-spring type is superior to the hydro-pneumatic in almost every respect. The writer is firmly convinced that future design should employ the hydro-spring type for all calibers below the 6-inch gun and 8-inch howitzer and feels that there is a strong argument for the hydro-spring type for even these calibers.

Professional Notes

Artillery Division

155-mm. Gun—Model 1920 E. MI.

THIS type gun is of the wire-wound type, the important elements consisting of a wire-wound tube, a jacket and a breech ring.

Three clip hoops, connected to the jacket by keys, dowel plugs and shrinkage carry the rails which connect the gun to the cradle. A lug on the breech ring connects the gun to the recuperator rods.

The characteristics of the gun are as follows:

Length of gun in calibers, 45; muzzle velocity, 2,800 f. s.; weight of projectile, 95 pounds; max. powder pressure permitted, 38,000 pounds per sq. in.; weight of gun, 9,372 pounds.

The breech mechanism in this gun and the action during operation are similar to the 8-inch howitzer Mark VI and VIII½ (Vickers), Model of 1917. The important feature, however, is the introduction of translation during rotation of the breech block so that the slope of the gas-check seat is materially reduced; this translation has no effect on the speed of opening and closing the mechanism.

The following is a comparative table of the angle of the gas check slope in carrier types of mechanisms:

8" howitzer, Mark VIII½ (Vickers)	14°	2′
155 mm. Gun (G. P. F.) (French)	17°	56′
155 mm. Gun, Model of 1920-E MI, U. S. A.	6°	0′

The translation in this mechanism is accomplished by the introduction of an additional arm on the crank acting in a cam cut in the periphery of the block and a member mounted on the carrier to which the block is engaged. The block is rotated by this member and as the threads of the block are disengaged from the locked position, the additional arm on the crank engages the cam on the block, retracting it to the rear while the block still continues its rotating motion, the roller on the member which is engaged in the cam on the rear face of the breech ring adds the opening movement of the carrier to the retraction of the block and provides opening energy to the carrier as it wings clear of the breech of the gun.

This gun is now under test at the Aberdeen Proving Ground. The breech mechanism was opened and closed 505 times rapidly at 11 degrees elevation and a primer fired every tenth time. Total time 3½ minutes. The limiting elevation at which this mechanism can safely be operated (without counterbalance) is 20 degrees, and to open and close rapidly 50 times at this elevation and fire a primer every tenth time consumed 3 minutes and 36 seconds. The mechanism was operated about 200 times before firing as a preliminary test to check the smoothness of the motion.

During the test the service velocity of 2,800 feet per second was obtained with a pressure of 37,000 pounds per square inch. The charge for the ninth round was estimated to give 42,550 pounds per square inch, or 115 per

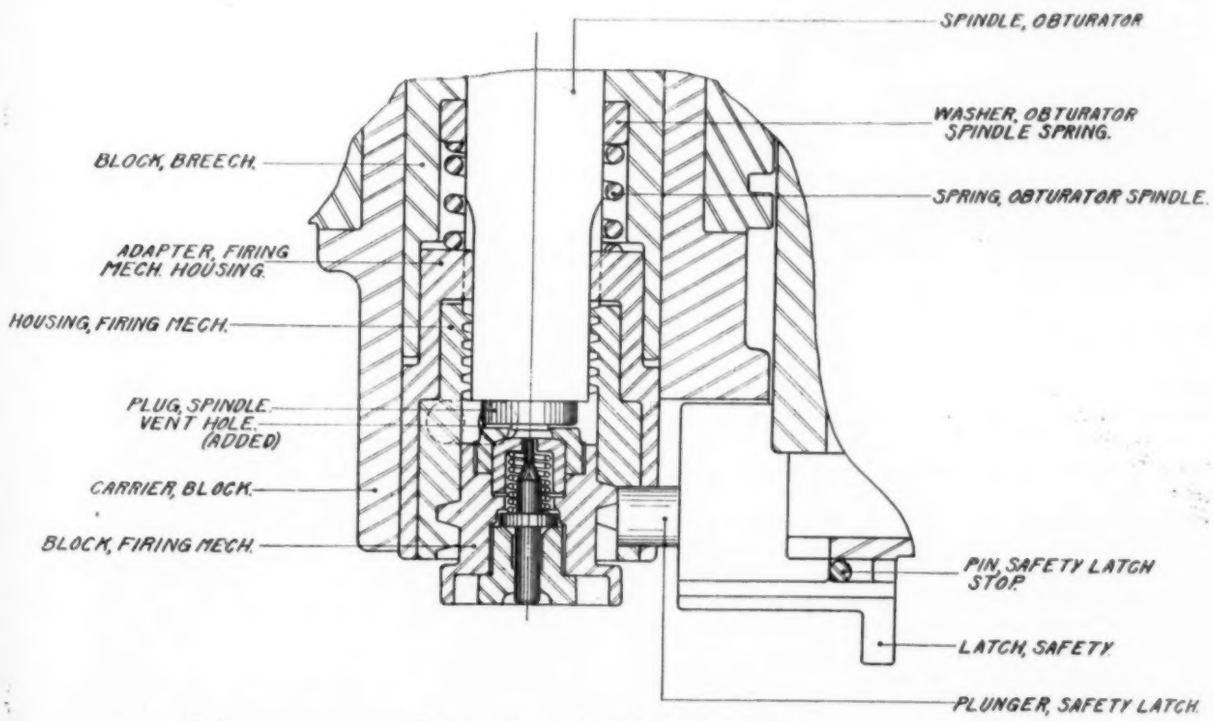


Fig. 1. 155-mm Gun, Model 1920E, MI

cent of the pressure found to give the service velocity of 2,800 feet per second. The actual pressure obtained with this charge was 48,700 pounds per square inch and caused a failure of the firing mechanism housing which together with the firing mechanism block was blown about 100 feet to the rear of the gun.

As the maximum powder pressure permitted is 38,000 pounds per square inch the 115 per cent testing charge should not have been over 38,000 × 1.15 = 43,700 pounds per square inch. The bore of the gun was star gauged after this round and no enlargement was discovered.

It is thought that the failure of the firing mechanism housing was caused by the rupture of the primer case which would allow an excessive pressure to build up in front of the firing mechanism block. To eliminate this a 0.5 diameter vent hole has been drilled through the carrier, firing mechanism housing and adapter, coming through in front of the firing mechanism block so that in the event of a ruptured primer the pressure on the front of the firing mechanism block will be practically eliminated.

The breech mechanism after this excessive pressure functioned as smoothly as at the beginning.

The Monarch 6-60.

Monarch Tractors, of Watertown, Wis., have, after a year of development work, brought out a new model industrial tractor which they have rated and named the Monarch Industrial 6-60.

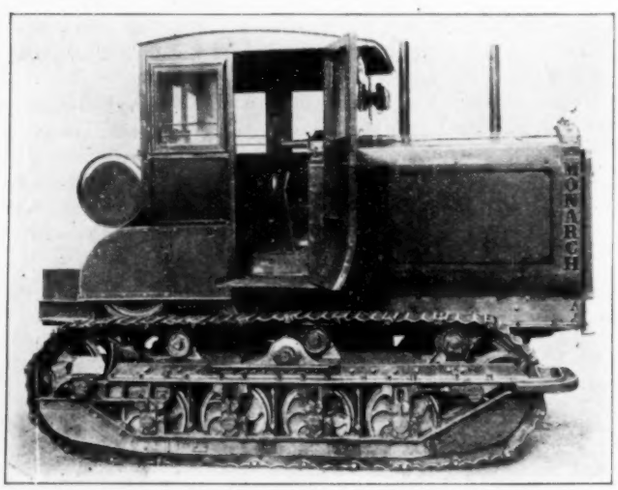


Fig. 2. The Monarch Industrial Tractor, Model 6-60

Chief among the new features is the mounting of the tractor frame at its three points of suspension upon heavy resilient, silico manganese springs. The rear spring is pivoted under the frame and in combination with the side springs forms a flexible three-point support, which prevents distortion or road shock from reaching motor or transmission.

Another advantage of the design of this new model is the provision for practical installation of electric lighting and starting equipment. Large reversible headlights make night work an easy possibility and the electric starter conserves gas and oil usually consumed in idling the motor and saves time in starting a cold engine.

Special alloy steels selected to carry the heavier loads and stresses, insure continuous and consistent operation without delays occasioned by breakdowns and repairs.

It is claimed that the new model is a finished product from an engineering standpoint and that it marks great advance in tractor design.

Power Plant.

The new six cylinder, heavy duty motor in this tractor is the same general design as that of the Monarch four cylinder type. Salient features are, six cylinders, 4¾ x 6, large overhead valves, removable cylinder heads, twin cylinder blocks, force feed oiling, through crankshaft, chrome nickel steel crankshaft with four main bearings, geared fan drive, tubular radiator with replaceable core, magneto with impulse starter, hand hole plates on both sides of crankcase, vacuum feed and Stromberg carburetor.

Three Speed Transmission.

The transmission is designed along the same lines as the unit which has been used in the Monarch four cylinder tractor over the last three years. All parts are much heavier and stronger throughout to carry the increased power developed by the new six cylinder engine. It has three speeds forward and one reverse.

The change gears in the transmission are forged nickel steel, heat treated. All shafts are also nickel steel, heat treated for maximum strength. Extra large Hyatt roller bearings carry the radial loads while the thrust loads are carried by heavy, double row, New Departure ball bearings.

The entire transmission runs in a bath of oil and is enclosed in an oil-tight and dust-proof case.

Clutch.

A three plate "Twin Disc" clutch and double flexible fabric coupling transmit the engine power to the transmission. A clutch and service brake is operated in combination with the clutch lever.

Steering Brake.

Large twenty-inch brake drums and band brakes with special moulded brake lining insure long life and easy steering.

Chains.

Heavy 2½-inch pitch nickel steel chains provide a flexible drive between the transmission and oscillating crawler.

Frame.

The frame is built up of heavy eight-inch channel steel securely braced and riveted. Heavy channel steel bumpers are built in to protect the machine, both front and rear. The tremendous strength of this construction maintains perfect alignment of all parts mounted upon it.

Crawlers.

The crawlers are of the rigid type of construction, oscillating on the main axle freely and independently of each other. Field experience has proven beyond a doubt that the rigid type of crawler, properly constructed, will bridge over inequalities of the surface with greater efficiency in respect to power and with correspondingly greater fuel economy than any other type of crawler design. The manufacturers claim that by riding on the high spots and bridging the low spots they have less power waste than any construction which attempts to conform to all inequalities of the ground and crawls in and out of the hollows and over the stones and mounds.

The oscillation of the Monarch crawlers on the main axle provides two independent tractive members. The several units forming the crawler chassis are the two crawlers,

the main axle, radius rods, springs, pivot sprockets and drawbar. The crawlers have a built-up frame the angles inches wide and ⅝ inch thick. The truck frame braces inches wide and ⅝ inch trick. The truck frame braces are ⅜ x 1¾ inch bars riveted together. The truck frame angles are securely bolted to the pivot bracket, spacer and rear axle brackets, and in combination with the truss bars and braces form a backbone of enormous strength for crawler construction.

The heavy one-piece steel radius rods are anchored securely to the crawler frame and pivoted over the main axle, permitting the vertical oscillation of the truck and yet forming at the same time a rigid brace to hold the crawlers in alignment. The rear ends of the radius rods form an outbound bearing and brace for the rear sprocket shafts and, through an equalizing spring or balance beam, support the rear end of the tractor frame.

The track sprockets are so designed that each tooth engages another and similar tooth on the track shoe with the least possible wear. Both teeth have broad, flat surfaces and the track sprocket engages squarely against the track without rubbing or grinding—patented feature of Monarch design. The teeth on the sprockets are flanged to guide the track and keep it in line at all times. It is claimed that Monarch Tractors cannot jump their tracks.

The track sprockets are cast chrome-nickel manganese steel, heat treated for requisite toughness and wearing qualities. The rear track and chain drive sprockets are a press fit on a hardened and ground nickel steel shaft. These sprockets and shafts make a unit assembly, which is carried in the rear axle bracket and rear radius rod heads by split bronze bushings. These bearings are lubricated by the same type of filter gravity as used on the track wheel bearings.

The construction permits the use of large diameter roller or twin wheels of car wheel type, which roll-over the manganese rail on the track shoe with less power waste and friction, it is claimed, than the small rollers used in other types of design.

The heavy 2-inch diameter track wheel shafts run in new type self-oiling bearings with floating bushings. The method of oiling these bearings is by oil pockets carrying a sufficient quantity of oil for a day's run. The feed of oil from the pocket is controlled by a felt filter which allows the oil to seep through, maintaining a constant feed of oil to the bearing. This oil pocket is located above the bearing and provides a gravity feed and positive lubrication. The hubs of the track wheels are extended out to partly enter the journal boxes, and have heavy felt packing pressed between their faces and the counter bore of the journal boxes. Replacement of the bearing in this journal box has been made a simple operation. The bushing floats in the journal box and it is only necessary to take out four cap screws, pull out the bearing box and replace the bushings.

Fig. 3. Budd Pressed Steel Artillery Wheel

Pivot Axle.

The crawlers are pivoted on a heavy 4-inch main axle which is turned down at the ends to form a shoulder which spaces the trucks the correct distance apart. The trucks are also braced by two radius rods pivoted over the center of the main axle and rigidly bolted to the truck frame. The rear end of the radius rod is fitted with split bronze bushings and forms an outboard support for the rear axle.

Pivot Sprockets.

The pivot sprockets mounted on the main or pivot axle run on large Hyatt roller bearings. Careful provision has been made by felt packing, etc., to retain oil in the bearings.

Drawbar.

The Monarch principle of mounting the drawbar on the crawlers only, is continued in this new model. This feature of Monarch construction relieves the tractor frame from all twisting and turning strains which may be produced in handling the tractor and load over rough places or within a small turning radius.

A drawbar plate is hung in sockets on the inner side of each crawler frame. Attached to this drawbar plate is a housing carrying a heavy coil spring. This coil spring and its assembly form a cushion to prevent excessive shocks in starting and hauling heavy loads. A heavy steel swinging drawbar is attached to this spring and supported at the rear by a steel casting, arranged to carry socket or "rooster" to take the push in holding back heavy loads going down hill or steep grades.

Artillery Wheels

In view of the difficulties involved in the manufacture of artillery wheels with wooden spokes and felloes and their rapid deterioration in service if not properly cared for, various attempts have been made to develop a satisfactory design of steel wheel as a substitute for the standard artillery wheel. Thus far, all the proposed experimental types of steel wheels using the steel tire have failed after a relatively short road test; and all types using solid rubber tires have likewise failed, with the exception of one pair of Budd pressed-steel rubber-tired wheels which were tested in 1919. These wheels have a hub and brake drum adapted to fit the standard 56-inch axle, the sides being made of two pressed steel plates with spokes pressed therein as shown on accompanying figure. This pair of wheels was placed on a 3-inch gun caisson, Model 1916, and road-tested for 1002 miles at a speed of approximately 10 miles per hour. At the completion of this test thorough inspection of both the caisson and wheels was made and no difficulties were recorded. The weight of one wheel is 401 pounds as compared with 370 pounds for the standard 57 x 3½-inch rubber-

tired wheel and approximately 200 pounds for the standard 56-inch wheel.

Tests were also conducted of two 61 x 6-inch disteel wheels manufactured by the Detroit Pressed Steel Company. These wheels were made up in accordance with the regular disteel construction and were provided with the standard 61 x 6 inch rubber tires. They were tested on a 4.7-inch gun caisson for a distance of 992 miles at speeds ranging from 8 to 13½ miles per hour. Some difficulty was experienced in the tires coming loose on the felloe bands and moving laterally. This was due, undoubtedly, to the small allowance made between the circumference of the felloe band and the circumference of the base band for the press fit. At the conclusion of the test one of the wheels was found to be in good shape while the other showed a weakness in the disc at the felloe. The wheel which failed had a disc thickness near the felloe of .135 inch, while the other had a thickness of .18 inch. It is thought that with a slight increase of the disc at the felloe the wheel would be practical for use on artillery vehicles. The weight of one wheel of this type is 750 pounds, as compared with 703 pounds for the standard 61 x 6 inch rubber-tired wheel, and 400 pounds for the standard 60-inch steel-tired wheels.

It is believed that wheels of either the Budd or disteel type would be satisfactory for artillery purposes when used with rubber tires, but it is doubtful whether either of these wheels would stand up properly if equipped with a steel tire.

Watervliet Arsenal

Removal of Wornout Liner from 14-inch Gun Model 1910 M1, No. 13.—Watervliet Arsenal was recently called upon to reline 14-inch gun, Model of 1910, M1, Number 13. The first operation in the relining of a gun is to remove the worn-out liner, if the gun was originally built with one, or bore out the tube in order to provide a seat for a new liner. The removal of the worn-out liner in this 14-inch gun was accomplished under unusual and unique conditions. In general the liners from the large guns are removed by dropping the liner from the gun, that is, the complete gun is heated in the furnace to the desired temperature and the liner refrigerated by passing cold water through it until it is contracted sufficiently to free itself from its seat in the gun.

The gun referred to in this article differs in construction from guns built today, in that the gun was built upon the "A" tube or liner; the "B" tube, or the tube which is assembled over the "A" tube being first rough turned and finished-bored for the liner or "A" tube, the liner seat having a taper of .005-inch on the diameter per inch of length. The liner is then turned to a prescribed shrinkage of .005-inch on the diameter from the breech end of the shoulder and .008-inch on the diameter from the shoulder to the breech end; the remainder of the gun being built upon these two members, whereas in the later type guns the liner is assembled last in the gun which is built up on the "B" tube.

With this method of construction, the resultant compression on the liner is due only to the shrinkage used in assembling the liner, whereas in the gun described in this article the compression on the liner is the resultant of the various shrinkages used in assembling the several hoops and the wire which go to make up the complete gun.

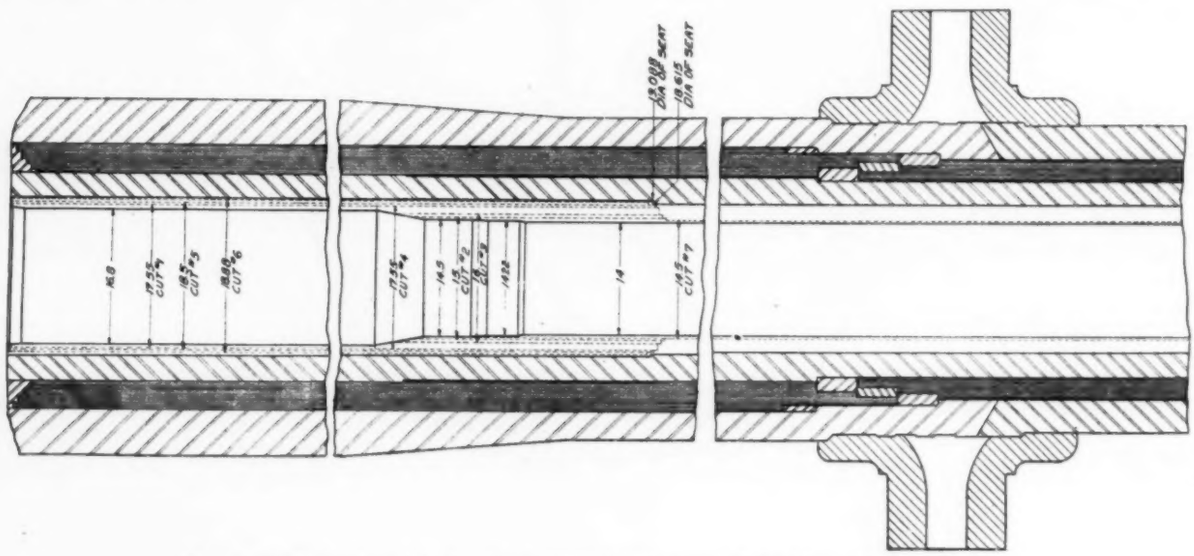


Fig. 4. Method of rough-boring liner preparatory to removal by taper reaming—Stage A

Watervliet Arsenal previously removed a liner from a 14-inch gun similar to the one described in this article by dropping the liner intact from the gun (this operation was described in the May-June, 1922, issue of ARMY ORDNANCE) but the compression on the liner was so great that the gun had to be heated to 700° F., with the result that the physical properties of the wire were affected to the extent that there was a loss of compression which affected the tangential resistance of the gun. Therefore it was necessary to adopt a new method in removing the liner from the second gun of this type.

In the manufacture of Model 1910 M1 guns the bore of the liner is tell-taled after assembly of the tube and liner and if found to run out more than 1/16-inch when both ends are held true the muzzle end of the tube is thrown to divide the runout as nearly equal as possible. The exterior of the tube is then respotted and turned to the prescribed diameter for wiring; the wire and exterior hoops are assembled, and the gun finish-bored and turned. Due to the distortion of the bore from the shrinking of the tube liner and to the subsequent throwing of the assembled tube and liner to correct the runout

to the best advantage, the outer diameter of the liner and the finish bore in the liner (or gun) are not concentric in guns of this model. The liners in all guns of this type are made with the exterior surface tapered to facilitate assembly and removal. The taper as previously mentioned is .005-inch on the diameter per inch of length.

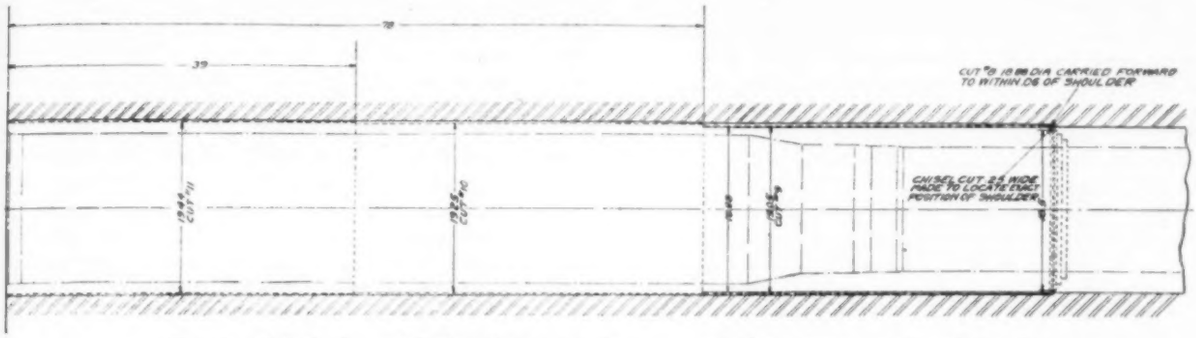


Fig. 5. Method of rough-boring liner preparatory to removal by taper reaming—Stage B

Since it was impossible to remove the old liner by unshrinking the only other method to remove it was by boring it out, and it is desirable to accomplish the boring operation without the slightest scoring of the liner seat in order to use the old seat without re-machining, and also to star gauge it to determine whether or not the various stresses to which the gun had been subjected in any way affected the original dimensions of the liner seat, in other words, to determine whether or not the wire and exterior hoops of the gun still exerted their original compressive force on the tube.

When this gun was returned for relining it was found to have a bend of approximately .09-inch between the muzzle and breech ends; the bend being approximately in the middle of the gun. This bend is in addition to the original but unknown eccentricity which results as before mentioned between the finish bore and exterior of the gun and the liner seat. With these variations to contend with the difficulty of the machining operation for the removal of the liner can easily be appreciated.

The removal of the liner from this gun was accomplished in the following manner. The muzzle of the gun was held in a lathe chuck and thrown about .18-inch in order to make the breech section up to the trunnions run true; the exterior breech end of the gun being run in a steady rest with a second steady rest applied directly in front of the trunnions to assist in carrying the weight of the gun. In this position the breech end of the liner was bored out by a succession of reaming cuts to a diameter of 18.88 inches, stopping short of the shoulder about ⅜-inch. Metal to a diameter of 18.50 inches was removed from the end of the tube for a distance of approximately ⅜-inch forward of the shoulder as shown in Fig. 4.

The exact location of the shoulder was then determined by chipping a narrow slot at an angle of 45° across the corner at the junction of the 18.88 inches and 18.50 inches diameters to locate the corner. See Fig. 5. The 18.88 inches diameter bore was then continued forward to within .06 inch of the shoulder. Four (4) exploration holes located about 90° apart around the circumference were not chipped close to the shoulder through the remaining shell of the liner, using a chisel about ¼-inch wide. These holes were provided for the purpose of determining the runout of the liner seat.

Measurements measuring the depth of these holes from the 18.88 inches diameter bore indicated a maximum runout of the liner seat at this point of .018-inch. The bore was now enlarged by one reaming out to a diameter of 19.05 inches, this reamer being carried forward to a point just short of breaking through at the shoulder, leaving only a fin of metal. As the diameter of the liner seat in front of the shoulder, according to the original star gauge records was 19.088 inches, with a runout at the same point as previously determined of .018 inch, this left a shell of the liner in front of the shoulder of a thickness varying from .01-inch minimum to .028-inch maximum. The actual separating of the liner at the shoulder was then accomplished by chiseling through the thin remain-

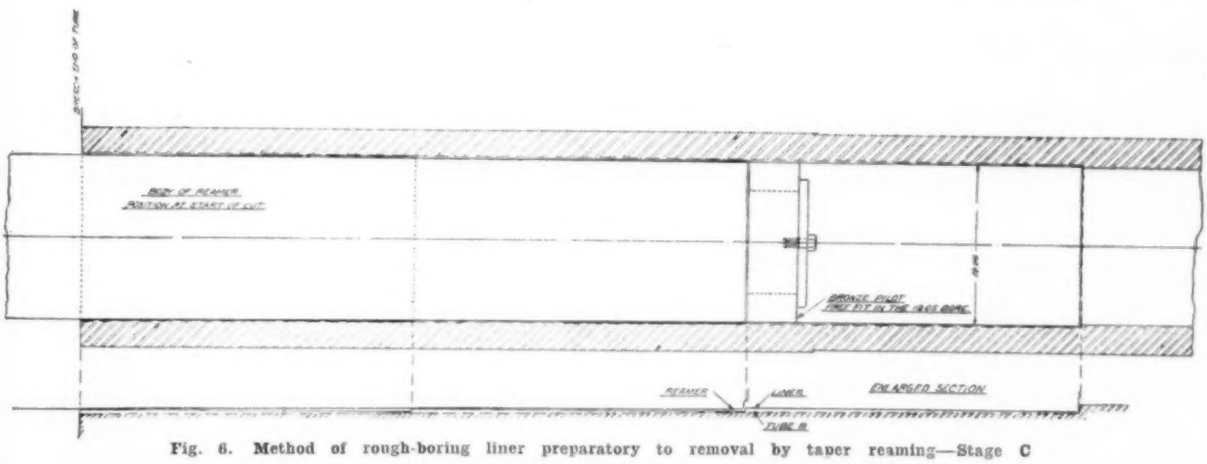


Fig. 6. Method of rough-boring liner preparatory to removal by taper reaming—Stage C

ing shell at the shoulder. The bore was then enlarged by one reaming cut to 19.25-inches diameter for a distance of 78 inches from the breech or within 39 inches of the shoulder and again to 19.44-inches diameter for a distance of 39 inches from the breech, thus dividing the partly bored out section of the liner into three (3) zones of 39 inches each. See Fig. 5.

A taper reamer such as is used for finish reaming the liner seat except somewhat smaller in diameter was next used to ream out the remaining shell of the liner. See Fig. 6. A 1/10-inch feed was used on this cut and the reamer withdrawn several times as the cut progressed, the bore being carefully inspected each time to determine whether or not the liner shell showed any signs of buckling away from the seat.

Finally when the nose of the reamer was within 13 inches of the shoulder, a section of metal about 12 inches to 14 inches long by 8 inches wide on the circumference of the liner showed distinct evidence of being loose from the seat. It was therefore decided that it would be unsafe to advance this reamer further into the bore and the remaining shell was removed by being split on one side, first chiseling through a short distance where it showed loose from the seat, then bending the edges up at the cut and forcing the jaw of a tinsmith's shear under the shell cutting the shell in two from end to end.

After being split, the shell still remained in contact with the seat so that it was necessary to introduce fine wedges in the joint at the breech end close to the split and move them around the circumference until finally the shell snapped loose and was withdrawn by hand. When withdrawn, the shell was found to be curled up on itself to the extent that the edges of the split lapped by each other about one-third of the circumference at the breech end with only about a 2-inch lap at the muzzle end. After removal the shell was measured and found to vary in thickness from .009-inch minimum to .035-inch maximum.

Telltaling of the original liner seat after removal of the liner indicated a runout at the shoulder of .04 inch about 29 feet from the breech end of the tube. In this telltaling the breech and muzzle ends were chucked true and the breech end of the gun held true by a steady rest applied in front of the trunnion, thus eliminating the bend in the gun and giving a true record of the warping that took place when the tube and liner were originally assembled.

It will be noted that in manufacture of this particular gun, the muzzle end of the assembled tube and liner had not been thrown to divide the runout caused by assembly of the two members; the runout being less than 1/16 inch.

The gun was now reversed in the lathe, the breech end chucked to run true, the muzzle end supported in a steady rest and the middle portion of the gun forced to run true by steady rest applied in front of the trunnion. The bore was then enlarged by two (2) reaming cuts to 16-inches diameter through the entire length of the liner that was left in the gun. The gun was again reversed in the lathe with the middle supported as before and the 16-inch bore enlarged in one (1) cut to 17 inches for a distance of 388.77 inches from the breech end of the tube; this reamer being centered by means of starting strips from the original liner seat to the rear of the shoulder. The bore was next enlarged by two (2) cuts to 18.057-inch diameter for a distance of 209.57 inches from the breech end of the tube.

Exploring for a runout at this point an eccentricity of .02 inch was found. This section of the shell was now taper reamed in the same manner as the rear section, the reamer being centered from the original seat the same as the roughing reamers, and the remains of the shell removed in the same manner.

From this point on, the remainder of the liner was divided into four (4) zones of equal length; each zone being rough-bored, explored, taper-reamed and the remains of the shell removed in the manner described above, except that the shell for the last two (2) zones was removed in one piece, when the gun was removed from the lathe after the last taper reaming cut. This procedure was considered safe since no runout was found when exploring the bore after rough boring the second one of the four (4) zones and the muzzle end was known to run true.

The entire operation of boring out the old liner consumed fourteen hundred and thirty (1430) man hours. This did not include tool preparation. Considering the difficulties that had to be overcome on account of the unknown eccentricity of the liner seat, the bend in the gun and the fact that not the least score in the liner seat was permissible and the consequent development work as regards methods to be used in removing the liner that had to be done in order to make certain of accomplishing the desired results, it is thought that the removal of the liner was accomplished in record time. In fact, the original estimated time called for fourteen hundred (1400) man hours.

Star gauge measurements of the liner seat taken after the removal of the liner as compared with the original records of the seat taken before assembly of the tube and liner showed but slight variations from the calculated dimensions, thus proving that the tangential strength of the gun had not been affected by firing.

Frankford Arsenal Rifle Club Breaks World Record

The team representing the Frankford Arsenal Rifle Club in the Small Bore Palma Competition held at Sea Girt, N. J., on July 4, 1923, won the match from a field of eleven teams by a score of 888 out of a possible 900 points. This is a new world record. The best record over the same course heretofore was 882 out of a possible 900. The Palma Match Course is 15 shots each man at 150 yards, 15 shots at 175 yards and 15 shots at 200 yards.

The previous world record over this course for any individual was 224 out of a possible 225, last made by Col. C. E. Stodter, U.S.A., in the Palma Individual Match on July 2.

The Frankford Arsenal Club team was composed of the following:

Captain of team—Mr. James Terry. Members of the team—Capt. Roy L. Bowlin, Ord. Dept., U.S.A.; Messrs. C. S. Hogue, C. R. Johnson, Alex Eisenhower.

Individual scores were as follows: Range 150 yards, highest possible score per man 75 points: Bowlin 75, Hogue 75, Eisenhower 73, Johnson 75.

Range 175 yards, highest possible score per man 75 points: Bowlin 75, Johnson 75, Eisenhower 75, Hogue 74.

Range 200 yards, highest possible score per man 75 points: Bowlin, 74, Eisenhower 73, Hogue 73, Johnson 71.

Reserve Corps Notes

Thirty-three Reserve Officers were trained during the period from June 15 to June 30, on procurement duty, at Frankford, Watertown, Watervliet and Springfield Arsenals. The course of instruction consisted of a series of lectures with two lectures each day The balance of the day was spent in general study and inspection of manufacturing activities of the respective arsenals. Due to the widely varied activities of each arsenal a similar course of instruction could not be followed.

The following have accepted commissions in the Ordnance Reserve Corps since last issue of Army Ordnance: Lt. Col. Samuel D. Foster, Lt. Col. Henry O. Bernhardt, Maj. Allen H. Clarke, Maj. Jesse G. Crownhart, Maj. James A. Fullam, Maj. Ralph P. Johnson, Maj. Frederick L. M. Masury, Maj. Harry Unwin, Capt. Benjamin M. Sawyer, Capt. Victor J. Vashon, Capt. Samuel C. Williams, 1st Lt. Alfred E. Ryan, 1st Lt. Samuel A. Smith, 2nd Lt. Donald D. Alexander, 2nd Lt. Delaney L. Frederick, 2nd Lt. Frank B. Golley, Jr., 2nd Lt. John L. Hodgkins, 2nd Lt. Lewis E. Limbert, 2nd Lt. Arthur R. Lytle, 2nd Lt. Edwin J. Parry, 2nd Lt. Leo K. Perry, 2nd Lt. George R. Swett, 2nd Lt. John S. Taylor.

Small Arms Inspection Course

Although existing regulations have prescribed a course of two weeks' active duty per year for officers of the Reserve Corps, this is the first time that the Ordnance Department has been able to train Reserve Officers for their period of active duty at manufacturing establishments.

During the period from June 15 to June 29, nine Reserve Officers of the Ordnance Department were on active duty at Springfield Armory taking an inspection course in small-arms manufacture. These officers are assigned to ordnance districts and will be engaged on similar work in case of an emergency. The course was planned to give the officers as complete a survey of the manufacture of small arms as possible with the available facilities and within the limited time.

Maj. Earl McFarland, on duty at the armory, was placed in charge of the course. A mimeographed schedule of the course and instruction sheet was issued to each officer on his arrival, which furnished him with such general information as he should require, and completely allotted his working hours for the entire period, as well as furnishing him with a list of the lectures with their subjects.

The class was divided into three sections of three men each in order that more individual instruction might be obtained than would be possible with one large section. It was felt that such a division into sections should be made along lines of individual training and previous experience of the men. Part of the first period was devoted to a lecture on the Springfield rifle, describing its components and the functioning of each, and familiarizing those men who had not had experience with the weapon with its nomenclature and functions.

This preliminary discussion of the rifle proved a very valuable introduction to the shop course. The work in the shops was divided in such a way that each section followed through from forging to assembly each of the most important components of the rifle. After this brief study of the manufacturing, the sections were assigned for a longer period to the actual gaging of some particular component. In this way each man had an opportunity to study one particular piece in detail, to observe all the steps required to make this piece, to study and actually perform the gaging operations necessary to inspect the component and to familiarize himself in general with the method of manufacturing to prescribed limits. Each student was also furnished with a copy of the Ordnance Department pamphlet describing this arm.

A portion of the course was devoted to laboratory practice and methods. The various tests, both physical

Inspection course for Ordnance Officers Reserve Corps, Springfield Armory, Mass., June 15-29, 1923

Top row—First Lieut. John F. Drennan, Second Lieut. Richard A. Taft, Second Lieut. Harry A. King, First Lieut. D. G. McGregor, Ord. Dept., U. S. A., Asst. Instr. Center row—Capt. Melville L. Merrill, Capt. Chas. B. Mellen, Major Earl McFarland, Ord. Dept., U. S. A., Instr.; Capt. James B. Ramage, Capt. Chas. Carey. Bottom row—Second Lieut. Lewis B. Keil, Second Lieut. Norman DeF. Douglass.

and metallurgical were illustrated and the manner of using these tests as a check on manufacture was clearly explained. Two periods were devoted to work in the experimental building where the various methods of proof-testing of the finished rifle and of ammunition were gone into. An opportunity to observe the targeting of national match rifles on the range was given

A very interesting trip to the plant of the Colts Patent Fire Arms Manufacturing Co., at Hartford, enabled the students to compare the manufacture of small arms as conducted in a Government plant with a similar product on a commercial scale. Special attention during the trip was devoted to the .45 caliber automatic pistol, which is a standard issue to troops. The courtesy of this plant in making the trip possible and of Mr. Moore in personally conducting the class through the plant added considerably to the information obtained and to the general value of the trip.

The work in the shops was supplemented by a very interesting and instructive set of lectures given by Regular Army officers engaged in manufacturing work or as heads of departments in Washington. Practically the whole field of ordnance manufacture and administration was covered in these lectures. The course included one or more lectures by Maj. R. H. Somers and Capt. MacMorland, by Capt. Read Whipprecht on general subjects of organization and administration, including the ordnance district system. Technical lectures were given by Maj. H. K. Rutherford, Maj. W. C. Young, Maj. C. A. Walker, Maj. L. D. Booth, Maj. J. K. Crain, Maj. Lee O. Wright, and Maj. Earl McFarland on subjects upon which each is eminently fitted to talk. A very interesting and practical instruction on gages and gage manufacture was given by Mr. Elmer Bryant, of the Greenfield Tap & Die Co.

Col. B. A. Franklin, Ordnance, Officers' Reserve Corps, who is chief of the Bridgeport district ordnance office, gave a short talk to the class on the needs and purposes of the Organized Reserve, and an outline of the industrial preparedness program from the district point of view.

At the end of the course one period was set aside for the purpose of allowing each officer to write a report on the course in general, giving his impressions and suggestions and covering certain specific points, such as constructive criticism on the course in general, suggested improvements in operation or shop layout, based on observation during the course; suggestions for improving the relation between regular officers of the Ordnance Department and ordnance officers of the Officers' Reserve Corps and development of interest in ordnance work throughout the country at large.

The following officers of the Reserve Corps were on active duty during this course:

Capt. James B. Ramage, 54 Montgomery Ave., Holyoke, Mass.; Capt. Melville L. Merrill, 40 Ardmore Road, Hartford, Conn.; 1st Lt. John F. Drennan, 135 Massasoit St., Springfield, Mass.; 2nd Lt. Harry A. King, 747 State St., Bridgeport, Conn.; 2nd Lt. Richard A. Taft, 92 Belmont Ave., Springfield, Mass. These officers have been assigned to the manufacturing service with station at the Bridgeport district ordnance office in case of an emergency.

The following officers from other districts expressed their desire for active training at Springfield Armory on account of particular interest in small arms:

From the New York district: 2nd Lt. Norman DeF. Douglass, 265 West 81st St., New York City; Capt. Charles B. Mellen, Setauket, Long Island. Both of these officers have had considerable experience with small arms.

From the Baltimore district: 2nd Lt. Lewis E. Keil, 1420 R St., N. W., Washington, D. C.; Capt. Charles Carey, U. S. National Museum, Washington, D. C.

The interest shown by all officers taking this course and the information gained by each has shown that this method of training will prove of great value in building up an interested and active reserve. The course as followed provided a system of instruction which covered the work in an effective and an efficient manner and gave to these officers not only an outline of the work required in the inspection and manufacture of small-arms products, but also a broad view of the operation of the Ordnance Department and its functions in both peace and war.

It is to be hoped that the courses conducted this year can be increased in number and in personnel and enlarged upon in instruction, so that in years to come a regular training period for officers of the Reserve Corps may be expected and that provision may be made for improving and advancing the course with each period of instruction.

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ELIGIBILITY

American citizens who have held positions of responsibility in connection with the design, procurement, production, manufacture, inspection, test or supply of Ordnance during the World War, or who occupy positions in civil life which would render them available for assisting in the production of Ordnance in the event of war, are eligible for membership.

Date.....

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Recent Patents

Brief Descriptions of Inventions of Interest to Ordnance Engineers

Compiled by W. N. Roach, Chief, Patent Section, Office of the Chief of Ordnance

THE following patents covering Ordnance matériel have been issued during the past few months. They are grouped below according to classification.

Motorization of Artillery

Patent No. 1,450,465, issued to William C. Turnbull, assignor to Holt Manufacturing Co., discloses a tractor having an articulated truck running on endless self-laying tracks and having no thrust link at the points of articulation, but utilizing a link to maintain proper position of the trucks, and having a special form of spring mounting and means for pivoting the rear of the truck directly and loosely on the main frame so as to prevent the truck from falling away from the main frame when the vehicle bridges a ditch or depression. The patent also discloses a novel form of three point suspension for the main frame on the truck.

Patent No. 1,450,466, issued to William Turnbull, assignor to Holt Manufacturing Company, for chain track vehicle, shows a trailer wagon provided with endless, self-laying tracks.

Patent No. 1,450,468, issued to Elmer E. Wickersham, assignor to Holt Manufacturing Company, for tractor frame suspension, discloses a suspension for allowing a considerable amount of relative movement of the trucks without imparting such movement to the main body of the vehicle; the object being accomplished by providing for each self-laying track unit a continuous rigid truck roller frame, resiliently supported in relation to the main frame at its rear end and supported by a yielding equalizing mechanism at its forward end.

Patent No. 1,450,469, issued to Elmer E. Wickersham, assignor to the Holt Manufacturing Co., for tractor construction, shows a tractor having a one-piece frame, at the rear end of which is mounted a driving axle and transmission. Track units are pivotally suspended from the opposite ends of the axle, and are further connected in a resilient manner to the forward ends of the vehicle frame at two points by novel resilient equalizing means.

Patent No. 1,450,470, issued to Elmer E. Wickersham, assignor to Holt Manufacturing Co., for single point frame suspension. This patent shows the usual tractor main frame and oppositely disposed chain track truck units, the units being pivotally mounted on the main frame along a common transverse axis, and further provided with differential mechanism whereby movement of one unit will tend to move the other unit in an opposite direction with the result that the main frame will be moved a minimum distance in relation to the change in relative positions of the truck frame; the structure being provided with resilient means for accommodating excessive shock and overload.

Patent No. 1,450,471, issued to Elmer E. Wickersham, assignor to the Holt Manufacturing Co., for a tractor tread zlink, discloses a tread link having an integral link body and tread plate, the links adapted for inter-engagement without any special separate connecting means, and so formed as to be driven by a sprocket wheel having a single peripheral row of teeth or a plurality of rows of teeth; the link, discloses a tread link having an integral link body of the operative surfaces.

Patent No. 1,450,472, issued to Elmer E. Wickersham, assignor to the Holt Manufacturing Company, for a suspension for tractors, shows a special structure which permits the truck mechanisms to rock in a vertical plane relatively to the main frame and to each other, while imparting little or no movement to the main frame.

Patent No. 1,450,478, issued to George T. Arthur, assignor to the Holt Manufacturing Company, for track link, discloses a link having an individual oil reservoir for lubricating the pins and antifriction bearings, and a removable grouser plate adapted to overlap the plate of an adjacent link to form a continuous track surface.

Artillery

Patent No. 1,446,683, issued to Alfred Wolff, for breech for firing devices for guns, particularly adapted for shell mortars. This invention discloses a firing device in which the same member is employed for cocking and securing, or for releasing for operation, the firing device, and in which a signal bolt is provided, which, by its position, will indicate whether the firing device is cocked or not. The device is fired by aid of a member which is movable in all directions so that it may be operated from any side.

Patent No. 1,447,085, issued to Bryan P. Joyce, an employee of the Ordnance Department, and licensed to the United States Government, for a gun carriage, discloses special resilient members for hanging a gun carriage from its axle, the members adapted for release to allow the carriage to be connected directly to the axle to secure rigidity when firing.

HOTEL ASTOR

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The Most Centrally Located Hotel in New York

F. A. MUSCHENHEIM

Patent No. 1,447,086, issued to Bryan P. Joyce, an employee of the Ordnance Department, and licensed to the United States Government, for an equalizing device, discloses a gun carriage having a specific pivotal connection between the top and bottom carriages and a special means for limiting the spread of the split trail.

Patent No. 1,447,087, issued to Bryan P. Joyce, an employee of the Ordnance Department, and licensed to the United States Government, for a coupling, shows a special construction intended primarily for coupling the rod of a recoil mechanism to the lug of a gun barrel.

Patent No. 1,447,821, issued to Eugene Schneider, assignor to Schneider et Cie., for method and apparatus for the manufacture of metal tubes, shows a means for applying pressure to a metal tube, such as a gun tube, consisting of a deformable cylinder, which may be made of sheet metal, rubber, or other expansible material, which is placed within the tube to be compressed and rests against the inner walls thereof. Inlet and outlet ports are provided in one end of the cylinder so that fluid under pressure may be admitted thereto and withdrawn therefrom. To gain greater compression in certain areas of the tube than in others, the walls of the cylinder may be made thinner in those areas where a greater compression is required than in those areas where less compression is desired.

Patent No. 1,448,587, issued to Richard H. Arntzen, for a gun, discloses a gun having a plurality of barrels mounted in a block, and having a yoke mounted on the muzzle end, and a selectively operable connection provided between the muzzles and yoke whereby the muzzles of the gun may be adjusted outwardly and inwardly in relation to each other to allow the shells fired from the barrels to be bunched or spread as desired.

Patent No. 1,448,449, issued to John H. Sayres, for line-throwing gun, discloses a gun mounted on a flat base, to which its breech is pivotally secured, and a means connecting the gun barrel and base for elevating the gun.

Patent No. 1,450,558, issued to Charles A. F. Maze, *dit* Delamare Maze, for gun, discloses a gun barrel having a combustion chamber and a nozzle leading from the chamber toward the main bore of the gun, which nozzle is first contracted and then expanded toward the main bore, and a chamber between the nozzle and the main bore for the reception of a shell or projectile which has openings therein to allow escape of gases to the atmosphere before the shell has moved from its position of rest.

Patent No. 1,450,585, issued to Hannibal C. Ford, assignor to Ford Instrument Company, for a range and bearing keeper, discloses an instrument of this character having a fixed dial, and a rotary compass dial cooperating with the fixed dial for indicating the course of one moving object, a rotary pointer associated with a compass dial for indicating the course of a second moving object, and a gearing between the compass dial and pointer for simultaneously moving the dial and pointer together or moving the pointer independently of the compass dial.

Patent No. 1,451,848, issued to Eugene Schneider, assignor to Schneider et Cie, for a wheeled gun carriage, having a divergible trail. The patent disclosed a structure to enable the pivotal axis of the gun pedestal to assume its vertical position at all times notwithstanding the transverse inclination of the wheeled axle or the longitudinal inclination of the carriage head. To accomplish this the swivel pivot pin of the gun pedestal is mounted in a gun mount which is pivoted to the carriage head and upon which the elevating mechanism of the gun barrel is supported. The uprighting of the pivotal axis is produced either by a double transverse and longitudinal movement of the combined gun mount and elevating mechanism in the carriage head, or by a displacement of the gun mount relatively to the carriage head on the one hand, and of the combined carriage head and gun mount relatively to the wheeled axle on the other hand.

Patent No. 1,450,915, issued to Otto Eppenstein, assignor to the firm of Carl Zeiss, for a stereoscopic telemeter, discloses a stereoscopic telemeter containing two objectives, stereoscopic measuring marks arranged in the focal planes of the objectives and two oculars for observing both the object, the distance of which is to be measured, and the measuring marks, and two other marks disposed each upon the focal plane of the appertaining objectives for producing a subsidiary stereoscopic mark.

Patent No. 1,450,907, issued to Archibald Barr and William Stroud, assignors to Barr and Stroud, Ltd., for an apparatus for testing and recording the efficiency of range finder operators, discloses an instrument comprising marks, one a movable mark, movable from a fiducial position, optical means for viewing the marks and for producing a reduced image of the marks, a differential gear for moving the movable mark, and a pencil or stylus for recording on an enlarged scale the position of the movable mark relative to the fiducial position.

Ammunition

Patent No. 1,447,198, issued to R. L. Wright, for a super-fired cannon, discloses another attempt to secure long range by providing a projectile with a series of booster charges which explode successively while the shell is in flight. The structure for accomplishing this in the present instance consists of a series of nested, or telescoping, heavy walled shells, the nose of each outer shell being of less resistant material than the nose of the next inner shall so as to be pierced by the inner shell when the charge projecting that shell forwarded is exploded.

Patent No. 1,449,128, issued to Max C. A. H. Pape, assignor to the Firm Carbonit Aktiengesellschaft, for a water bomb. This bomb comprises a bomb proper and a float which detaches itself from the bomb when dropped in water and which is then connected to the bomb by a cable through which the igniting or firing mechanism is operated. The bomb is also provided with a noved form of fuse.

Patent No. 1,447,101, issued to Douglas L. Parkhurst, a former employee of the Ordnance Department, and licensed to the United States Government, for a fuse, discloses a fuse intended primarily for use in hand grenades. The fuse is so constructed that the primer first ignites a fuse or powder train having a predetermined period of burning, which train in turn ignites a combustible compound in a rocking element which is rocked on impact to ignite the main explosive charge. Should the grenade be accidentally dropped after extraction of the safety pin the rocking element will be rocked to its final position, where the charge can not be ignited.

Patent No. 1,447,551, issued to Clarence I. B. Henning, assignor to E. I. du Pont de Nemours and Company, for an igniting mixture, discloses a primer mixture formed from tetranitropentaerythrite, and other substances, such as potassium chlorate, antimony sulphide, and lead sulphocyanide.